PB85-191195

Historic Emissions of Sulfur and Nitrogen Oxides in the United States from 1900 to 1980. Volume 1. Results

Pacific Environmental Services, Inc., Durham, NC

Prepared for

Environmental Protection Agency
Research Triangle Park, NC

Apr 85

U.S. Department of Commerce
National Technical Information Service
NTIS

PB85-191195

EPA/600/7-85/009a
April 1985

HISTORIC EMISSIONS OF SULFUR AND NITROGEN OXIDES IN THE UNITED STATES FROM 1900 TO 1980

Volume I. Results

by

Gerhard Gschwandtner, Karin C. Gschwandtner and
Kevin Eldridge
Pacific Environmental Services, Inc.
1905 Chapel Hill Road
Durham, North Carolina 27707

EPA Contract No. 68-02-3511
Assignment No. 31 and 47

Project Officer:
J. David Mobley
Air and Energy Engineering Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

AIR AND ENERGY ENGINEERING RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO.
EPA/600/7-85/009a

2.

3. RECIPIENT'S ACCESSION NO.
PB85 191195/AS

4. TITLE AND SUBTITLE
Historic Emissions of Sulfur and Nitrogen Oxides in the United States from 1900 to 1980; Volume I. Results

5. REPORT DATE
April 1985

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
G. Gschwandtner, K. C. Gschwandtner, and K. Eldridge

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Pacific Environmental Services, Inc.
1905 Chapel Hill Road
Durham, North Carolina 27707

10. PROGRAM ELEMENT NO.

11. CONTRACT/GRANT NO.
68-02-3511, Tasks 31 and 47

12. SPONSORING AGENCY NAME AND ADDRESS
EPA, Office of Research and Development
Air and Energy Engineering Research Laboratory
Research Triangle Park, NC 27711

13. TYPE OF REPORT AND PERIOD COVERED
Task Final; 9/82 - 12/84

14. SPONSORING AGENCY CODE
EPA/600/13

15. SUPPLEMENTARY NOTES AEERL project officer is J. David Mobley, Mail Drop 61, 919/541-2612. Volume II contains report data.

16. ABSTRACT

The report gives results of an estimate of historic emissions of sulfur dioxide (SO2) and nitrogen oxides (NOx) for Task Group B, Manmade Sources, of the National Acid Precipitation Assessment Program (NAPAP) for each state of the conterminous U.S. The emissions were estimated by individual source category on the state level from 1900 to 1980 for every fifth year and for 1978. The source categories included power plants, industrial boilers, industrial processes, commercial and residential heaters, natural gas pipelines, highway vehicles, off-highway diesel engines, and all other anthropogenic sources. These emissions were calculated from salient statistics indicative of fuel consumption or industrial output, estimations of average statewide fuel properties, and estimates of emission factors specific to each source category over time. The emission estimates were then aggregated to show the emission trends by state, region, and all states combined. Total state emissions for each year were then estimated using an interpolation procedure based on national annual fuel consumption.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Pollution Control	13B
Sulfur Dioxide	Stationary Sources	07B
Nitrogen Oxides	Anthropogenesis	
Precipitation (Meteorology)	Acid Rain	04B
Acidity		07D

18. DISTRIBUTION STATEMENT
Release to Public

19. SECURITY CLASS *(This Report)*
Unclassified

20. SECURITY CLASS *(This page)*
Unclassified

21. NO. OF PAGES
118

22. PRICE

EPA Form 2220-1 (9-73)

NOTICE

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

This volume summarizes the historic emissions of sulfur dioxide and nitrogen oxides on the national, regional and state level from 1900 to 1980. It describes the methodology used to estimate the historic emissions of all point and area sources. Volume II of this series presents the individual state emission estimates by individual source category. A computer tape containing the data has been prepared to allow changes to be made to historic data as work in this area continues and as methods are further refined (see Volume II, page ii). The data base in these volumes is consistent and complete from state to state from 1950 to 1980. For earlier years consistent assumptions were made when state-level data pertinent to the development of emission estimates could not be obtained directly. As a result, the historic emission estimates provide the best basis at this time for comparing the spatial and temporal changes in emissions on the state level and for studying their relationship to trends in acid deposition, visibility, materials damage, and terrestial and aquatic effects observed and measured over past years. These trends and relationships are being studied by the National Acid Precipitation Assessment Program (NAPAP). This project was administered by the U.S. Environmental Protection Agency (EPA) with funding from NAPAP's Task Group B - Man-Made Sources. Under this program, Task Group B has the responsibility to provide a single consistent source of historic emission trends data. These data will be used by other Task Groups in their assigned studies. The report has been reviewed and approved for publication by appropriate EPA and NAPAP personnel.

David J Beecy

David J. Beecy, Chairman
NAPAP Task Group B - Man-Made Sources
U.S. Department of Energy

CONTENTS

Foreword. iii

Figures viii
Tables. ix
Abbreviations x
Abstract/Acknowledgment xi

Chapter I. PROJECT SUMMARY

1.0 Introduction. 1
2.0 Method. 3
  2.1 Approach for 1950 to 1980. 3
    2.1.1 Fuel Consumption. 3
    2.1.2 Emission Factors. 5
    2.1.3 Emission Controls 6
  2.2 Approach for 1900 to 1945. 6
  2.3 Assumptions. 7
  2.4 Aggregation of Emissions 7
  2.5 Yearly Estimates 8
3.0 Results for 1900 to 1980. 8
  3.1 Fuel Consumption, Overall and for Categories 7
  3.2 SO_2 Emissions, Overall and for Categories. . 10
  3.3 NO_x Emissions, Overall and for Categories. . 10
4.0 Analysis by Region. 14
5.0 Analysis by State 15
6.0 Analysis by Emission Release (Stack) Height . . . 15
7.0 Discussion. 20
8.0 Conclusion. 22
9.0 References for Chapter I. 22

Chapter II. METHOD OF DATA PRODUCTION

1.0 Definition of Source Categories 25
2.0 Sources of Data 25
  2.1 Salient Fuel Statistics. 27
  2.2 Fuel Sulfur Content. 31
  2.3 Emission Factors 33

Preceding page blank

CONTENTS (continued)

3.0 Calculation Procedures 33
  3.1 Electric Utilities. 34
  3.2 Industrial Boilers and Space Heaters. 35
  3.3 Commercial and Residential Uses 37
  3.4 Anthracite - All Uses 38
  3.5 Pipeline Compression Stations 38
  3.6 Highway Vehicles 38
    3.6.1 Gasoline-Powered Vehicles. 39
    3.6.2 Diesel-Powered Vehicles 42
  3.7 Railroads 42
  3.8 Coke Plants 42
  3.9 Primary Smelters. 43
  3.10 Vessels 44
  3.11 Off-Highway Diesel Engines. 44
  3.12 Cement Plant. 45
  3.13 Wildfires 45
  3.14 Miscellaneous 47
    3.14.1 Miscellaneous Industrial Processes. . . . 47
    3.14.2 Miscellaneous Other 47
4.0 Further Improvements 48
  4.1 Fuel Consumption. 48
  4.2 Sulfur Content. 49
  4.3 Emission Factors. 49
5.0 Quality Control. 49
  5.1 Comparison with Other Emission Estimates. 50
    5.1.1 National Comparison, 1940 to 1980. 50
    5.1.2 Comparison of Electric Utilities, 1975 to 1980 52
    5.1.3 Comparison with the 1980 NAPAP Emission Inventory. 56
  5.2 Probable Error of Estimates 56
6.0 Availability of Data on Computer Tape 57

CONTENTS (concluded)

Chapter III. METHOD OF ESTIMATING YEARLY EMISSIONS

1.0 Possible Approaches 58
2.0 Interpolation Procedure 59
3.0 Total Annual State Emission Estimates. 60
References for Chapters II and III 62

Appendix A - Interpolated Annual Total State Emissions . . 68
Appendix B - Total National Emissions by Season 100
Appendix C - Total National Emissions by Release (Stack) Height 104

FIGURES

Number Page

1 Total mineral fuel consumption of the United States by major source: 1900 to 1980. 9

2 Overall trend in SO_2 emissions from 1900 to 1980 for the United States and by fuel type 11

3 Overall trend in SO_2 emissions from 1900 to 1980 for the United States and by source category . . 11

4 Overall trend in NO_x emissions from 1900 to 1980 for the United States and by fuel type 12

5 Overall trend in NO_x emissions from 1900 to 1980 for the United States and by source category . . 12

6 Map of the EPA Administrative Regions. 13

7 Temporal changes in regional SO_2 and NO_x by source category from 1900 to 1980. . . . . 16 and 17

8 Total state emissions of SO_2 and NO_x for every tenth year from 1900 to 1980 . . . . 18 and 19

9 Annual SO_2 and NO_x emissions of the conterminous United States: 1900 to 1980 61

TABLES

Number		Page
1	Fuel Types and Emission Source Categories	4
2	Definition of Source Categories	26
3	References for State-Level Fuel Consumption Data, 1950-1980	28
4	References for State-Level Fuel Consumption Data, 1900-1945	29
5	National Fuel Consumption by Source Category, 1900-1950	30
6	References for Sulfur Content Data.	32
7	Power Plant Emission Reductions	36
8	Assumptions Regarding the NO_x Emission Factors for Highway Vehicles.	40
9	Assumed Values for Miles per Gallon	41
10	Miscellaneous Industrial Processes.	46
11	Miscellaneous Other Sources	46
12	Comparison between Aggregated State Totals and EPA National Estimates.	51
13	Comparison between Coal-fired Electric Utility SO_2 Emissions of this Study and those of Pechan, et. al. .	53
14	Comparison between Oil-fired Electric Utility SO_2 Emissions of this Study and those of Pechan, et. al. .	54
15	Comparison of Total State SO_2 and NO_x Emissions of this Study and the NAPAP Emission Inventory for 1980. .	55

LIST OF ABBREVIATIONS

ABBREVIATIONS

bbl -- barrel (42 U.S. gallons)
Btu -- British thermal unit (0.252 Kilogram-calorie)
cu.ft. -- cubic feet (0.028317 cubic meters)
gal -- U.S. gallon (3.7853 liters)
lb -- pound (0.45359 kilogram)
mi -- mile (1.6093 kilometers)
NA -- not available
ton -- short ton (906.18 kilograms)

ABSTRACT

Historic emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) were estimated for Task Group B, Manmade Sources, of the National Acid Precipitation Assessment Program for each state of the conterminous United States. The emissions were estimated by individual source category on the state level from 1900 to 1980 for every fifth year and for 1978. The source categories included power plant, industrial boilers, industrial processes, commercial and residential heaters, natural gas pipelines, highway vehicles, off-highway diesel engines and all other anthropogenic sources. These emissions were calculated from salient statistics indicative of fuel consumption or industrial output, estimations of average statewide fuel properties and estimations of emission factors specific to each source category over time. The emission estimates were then aggregated to show the emission trends by state, region and all states combined. Total state emissions for each year were then estimated using an interpolation procedure based on national annual fuel consumption.

ACKNOWLEDGEMENT

The authors are greatly indebted to Charles O. Mann, National Air Data Branch, U.S. Environmental Protection Agency who provided much guidance and assistance throughout this assignment and who served as technical advisor. Sincere appreciation is also extended to Rudolf B. Husar and to Frederick Lipfert for sharing information with us and for consultation and valuable suggestions. The authors are also indebted to many individuals in many agencies who provided copies of relevant historic data and to the staff of Duke University Library Reference Department for assistance in locating information. Suggestions and comments of the technical reviewers of the draft document are appreciated and hereby acknowledged. This assignment was supported by funding from Task Group B, National Acid Precipitation Assessment Program, through the U.S. Environmental Protection Agency.

CHAPTER I

PROJECT SUMMARY

1.0 INTRODUCTION

Sulfur oxides and nitrogen oxides are considered primary precursors of acidic precipitation. The anthropogenic emissions of these pollutants are suspected causes of many biological and chemical effects observed in recent years. Understanding the historic emission trends is important to understanding the development of acid precipitation-related problems and causes of observed environmental effects.

Annual quantities of emissions of sulfur oxides and nitrogen oxides are presented for each of the contiguous 48 states including the District of Columbia. Emissions of each pollutant were estimated for every fifth year from 1900 to 1980 and for 1978. The time span from 1900 through 1980 was selected to allow study of early alkalinity measurements and also to allow comparison with the 1980 national emission inventories being developed under the National Acid Precipitation Assessment Program. Five-year intervals were selected to provide an indication of the emission trends sufficient for most effects studies and to develop a methodology that could be applied to all other years. The state level was selected because it provides the most complete and consistent body of information on a historic basis and collectively covers all geographic regions of the country.

For each state the estimates are based on the apparent annual consumption rate of fuels. The fuels include bituminous coal, anthracite, lignite, residual and distillate oil, natural gas, wood, gasoline, diesel fuel and kerosene. The consumers of these fuels, which are also the emitters of sulfur oxides and nitrogen oxides, are categorized according to electric utilities, industrial boilers, commercial and residential furnaces, pipelines, highway vehicles, railroads, coke plants, smelters, vessels and other major sources. Emissions were also estimated for industrial processes based on production rates, wildfires and a miscellaneous source category. Collectively, these source categories account for all anthropogenic emissions in each state.

These emission estimates are improvements over previous estimates reported by Gschwandtner, et. al.[1,2,3,4] They are the result of refinement in methodology and further research. The original data file included only 33 eastern states and the District of Columbia and was limited to the time period between 1950 and 1978. This file provided the best estimates of the emission trends for these states available at the time, but it was recognized that the estimates for 1950 and 1955 were incomplete and inconsistent with later years and that further improvements in the methodology were needed. The present report incorporates many technical improvements, additional details and an expansion of the data file in both time and space.

The state-level emission estimates for point and area sources contained in the present report, supplement the national historic emission estimates of the U.S. Environmental Protection Agency[5] available for every tenth year from 1940 to 1970 and yearly since 1970. The state-level emission estimates in this report provide greater spatial resolution for the study of acid precipitation trends over a longer time period. These latest estimates also incorporate some information provided by other historic emission researchers. Information on emission trends for residential sources and highway vehicles inferred by Lipfert et. al. have been incorporated.[6] For years prior to 1950, estimates of state coal consumption estimated by Husar, et. al. have also been included in the data file.[7,8,9] Husar, et. al. used regional, state, and sub-state level coal consumption to indicate the emission trends of sulfur oxides in the early part of the century and late 1800's.[10]

This chapter summarizes the general methodology and the results of the current historic emissions data file available for each pollutant. Sulfur oxides are expressed as sulfur dioxide (SO_2) and nitrogen oxides (NO_x) are expressed as nitrogen dioxide to be consistent with the emissions reported by the U.S. Environmental Protection Agency. The next chapter describes specific methods of data production for each source category, compares the estimates with other emission inventories and discusses ways to further improve the estimates. Volume II of this series,[11] which replaces an earlier version (Reference 4) contains the historic SO_2 and NO_x emissions data file for each state by source category and the underlying fuel consumption and sulfur content data bases.

2.0 METHOD

Average emission rates for each study year were calculated for individual source categories for each state. The source categories are listed in Table 1 according to the type of fuel consumed. These categories represent all types of boilers, furnaces, engines, processes and other manmade emission sources. The basic steps involved in calculating state emissions are listed below:

1. Obtain state level information on fuel use.
2. Allocate fuel quantity used by each source category.
3. Develop source category emission factors.
4. Determine fuel sulfur content by state for each category.
5. Calculate emissions, after emission controls.

The actual procedure varied somewhat depending on the usefulness and availability of information. It can generally be described in more detail for two time periods; 1) 1950 to 1980, and 2) 1900 to 1945.

2.1 Approach for 1950 to 1980

2.1.1 Fuel Consumption

For electric utilities, state consumption rates of fossil fuels were derived by individual power plant from the Bureau of Census,[12] the American Petroleum Institute,[13] the U.S. Department of Energy,[14] and the National Coal Association.[15] The consumption rates were determined according to boiler type. For all other categories except smelters and miscellaneous sources, annual fuel consumption rates were obtained for the source category as a whole from various publications cited in Chapter II. When fuel consumption data were not available other salient statistics such as fuel sales, demand, distribution or shipments were used. For the highway vehicles category, vehicle miles traveled were used for 1970 to 1980 because these provided a better estimate according to the mix of vehicle types. For earlier years, gasoline consumption by state was used. For the wildfire category, total forest area burned in each state was used.[16] For smelters and miscellaneous industrial processes, estimates were based either on individual plant or state production rates. For 1950 to 1980, state-level fuel consumption data were available for most source categories.

TABLE 1. FUEL TYPES AND EMISSION SOURCE CATEGORIES

Bituminous Coal:	Electric Utilities
	Industrial Boilers and Space Heaters
	Commercial and Residential Uses
	Steam Railroads
	Coke Plants
Anthracite coal:	All Uses
Residual Oil:	Electric Utilities
	Industrial Boilers and Space Heaters
	Commercial and Residential Uses
	Vessels
Distillate Oil:	Electric Utilities
	Industrial Boilers and Space Heaters
	Commercial and Residential Heating
	Railroads
	Vessels
Natural Gas:	Electric Utilities
	Industrial Boilers and Space Heaters
	Pipeline Compression Stations
	Commercial and Residential Uses
Wood:	Electric Utilities
	Industrial Boilers and Space Heaters
	Commercial Heating
	Residential Wood Stoves and Fireplaces
Gasoline and Diesel:	Highway Vehicles
	Off-Highway Vehicles
	Vessels
Other:	Wildfires
	Cement Plants
	Copper, Lead and Zinc Smelters
	Miscellaneous Industrial Processes
	Miscellaneous Other Sources

2.1.2 Emission Factors

The state-level data were then multiplied by specially derived emission factors to yield estimates of uncontrolled emissions. First, the most recent emission factors of the U.S. Environmental Protection Agency reported in AP-42 and Mobile 2 were obtained.[17,18] These factors are based on actual emission tests of each type of combustion process or emission source represented in each source category. They are most appropriate when applied to a large number of sources such as on the state level. Periodically, they are revised by the Agency to include new, additional or improved test data.

The factors for each pollutant were then adjusted to represent each source category as a whole. This procedure involved mathematically weighting each factor according to the amount of fuel consumed by various types of boilers, furnaces, engines, processes or other emission sources comprising the category. For highway vehicles, NO_x emission factors were state specific and were weighted according to the amount of urban and rural traffic and state elevation, vehicle mix and pollution controls in use. These adjustments provided the most representative factors for 1970 to 1980 for which vehicle miles traveled were available. For earlier years, vehicle miles traveled are not available and the factors were based instead on gasoline consumption and on estimated average miles per gallon for both urban and rural traffic. These factors yield generally the same results as those of Lipfert derived from the trend in internal compression ratios of vehicle motors.[19]

SO_2 emission factors were also weighted according to fuel consumption by individual emission sources within each category. However, these factors are more dependent on fuel properties than on combustion sources and include a fuel sulfur content variable. The emission factors account for the fraction of the fuel sulfur that would be emitted as uncontrolled emissions and the remaining fraction that would be captured in the solid residue. These fractions are determined on the basis of source emission tests and materials balance analysis involving various coal ranks that are commonly used by each source. The average statewide values of sulfur content of coal on the consumer level were obtained from the Bureau of Mines for 1965.[20] For the earlier years, average statewide values were calculated from fuel distribution reports and information on fuel properties by originating district.[21,22] The calculation techniques are described in Chapter II. The average values of sulfur content of fuel oils were obtained from information published by the Bureau of Mines and the U.S. Department of Energy, Bartlesville Energy Technology Center for domestically produced fuel oils. These references are also cited in Chapter II.

2.1.3 Emission Controls

The amount of emissions controlled by certain control devices was then subtracted from each source category. This step pertained to SO_2 which is controlled by flue gas desulfurization systems at power plants and by-product sulfuric acid plants at smelters. Controls applied to sources of NO_x emissions have generally had little effect in reducing emissions through 1980.[5]

Estimates were then compared with EPA national emission estimates, with the NAPAP emission inventory for 1980,[23] and with the estimates of Pechan, et. al. for electric utility emissions.[24,25] This provided an indication of the precision of estimates for common years and a basis for establishing the precision for earlier years.

2.2 Approach for 1900 to 1945

For this time period, state-level data on actual fuel consumption by source category were not always available, especially for the earlier years. Also, the method for collecting and reporting early data was not always consistent with the method for more recent years. Depending on the type of information found, either one of three approaches was taken.

1. State-level data were used when available,
2. National data were apportioned to the states, or
3. No estimates were made when state and national data were unavailable and when the emissions were so small as to be considered negligible.

These approaches help account for most of the early SO_2 emissions which were dominated by coal usage and for which consumption data are available either on the state or national level. Most NO_x emissions are also accounted for by this approach, but in terms of quantity are comparatively less than SO_2 because of the low consumption rates of fuel oils and natural gas in the early study years.

2.3 Assumptions

The same sulfur content values derived for 1955 were assumed to apply to the earlier years. This assumption was necessarily made because no evidence was found to suggest a general trend in sulfur content. Available information indicates that sulfur content of coal as mined did not change significantly and most coal was consumed in or near the producing states. Analysis of coal distribution patterns also suggests little change compared to the changes in the middle or recent part of the century.

It was also assumed that the emission factors used for 1955 applied to earlier years. No evidence was found to suggest a change in either the emission characteristics of coal-fired sources or the population mix of types of boilers and furnaces. As research in historic emission patterns and trends continues, this general assumption may be replaced by specific state-level data if such data can be developed.

Other assumptions which were made are more specific to certain years and source categories and are described in Chapter II.

2.4 Aggregation of Emissions

Historic fuel consumption data were tabulated for each state according to source category and study year. Corresponding fuel sulfur content values were also tabulated for each source category according to state and year. A third tabulation contained the weighted emission factors for SO_2 and NO_x by source category and in some cases by state. These three matrices were multiplied to produce two new matrices, one for SO_2 emissions and one for NO_x emissions. The emissions of each state were then totaled by year to provide an estimate of overall national emission trends. They were also totaled by fuel type and by source category to show the effects of fuel switching and changes in consumer sectors. State emissions were also aggregated to show the trends in broad geographic regions of the country.

The national emissions were then analyzed by season and also by stack height ranges. For the seasonal analysis, the percentage distribution of the emissions by season was estimated for each major source category based on engineering judgment and known historic characteristics of each source category to give a general indication of the trend since 1900. The total national emissions of each source category were then multiplied by these percentages. As a result, the estimated seasonal emissions reflect both the trend in total emissions by source category and the general change in the seasonal distribution of emissions by source category.

For the release height analysis, the percentage distribution of national emissions was estimated for each source category according to four broad ranges of stack heights. In the case of electric utilities, individual power plant emissions and stack height data were used to determine the national distribution by height from 1950 to 1980.[2] For earlier years and for other sources, the analysis was based on the general trend in the stack heights for the category as a whole. Both the seasonal and stack height analyses provide an approximate indication only of the trend on the national level. The emission trend by season is shown graphically in Appendix B and by stack height in Appendix C. However, these results should not be considered as reliable as other information presented in this report.

2.5 Yearly Estimates

State total emissions for the intervening years were interpolated from the state emissions estimated for the study years and the annual national energy consumption reported by fuel type. The interpolation was performed individually for each major fuel category by state. For each intervening year, the emissions of each fuel category were then added. The interpolation procedure is described in Chapter III and the resulting state total emissions are presented in Appendix A.

3.0 RESULTS FOR 1900 TO 1980

National and regional trends of each pollutant are presented here by fuel type and by source category. The trend in total emissions of individual states are also shown while the individual state estimates for individual source categories are presented in Volume II.

3.1 Fuel Consumption, Overall and for Categories

Figure 1 shows the total mineral fuel consumption for the United States in terms of energy consumed by major source as obtained from the Bureau of Census.[26,27] Total coal consumption has remaine[illegible]latively constant over time since 1900 compared to the consumption of other fuels.

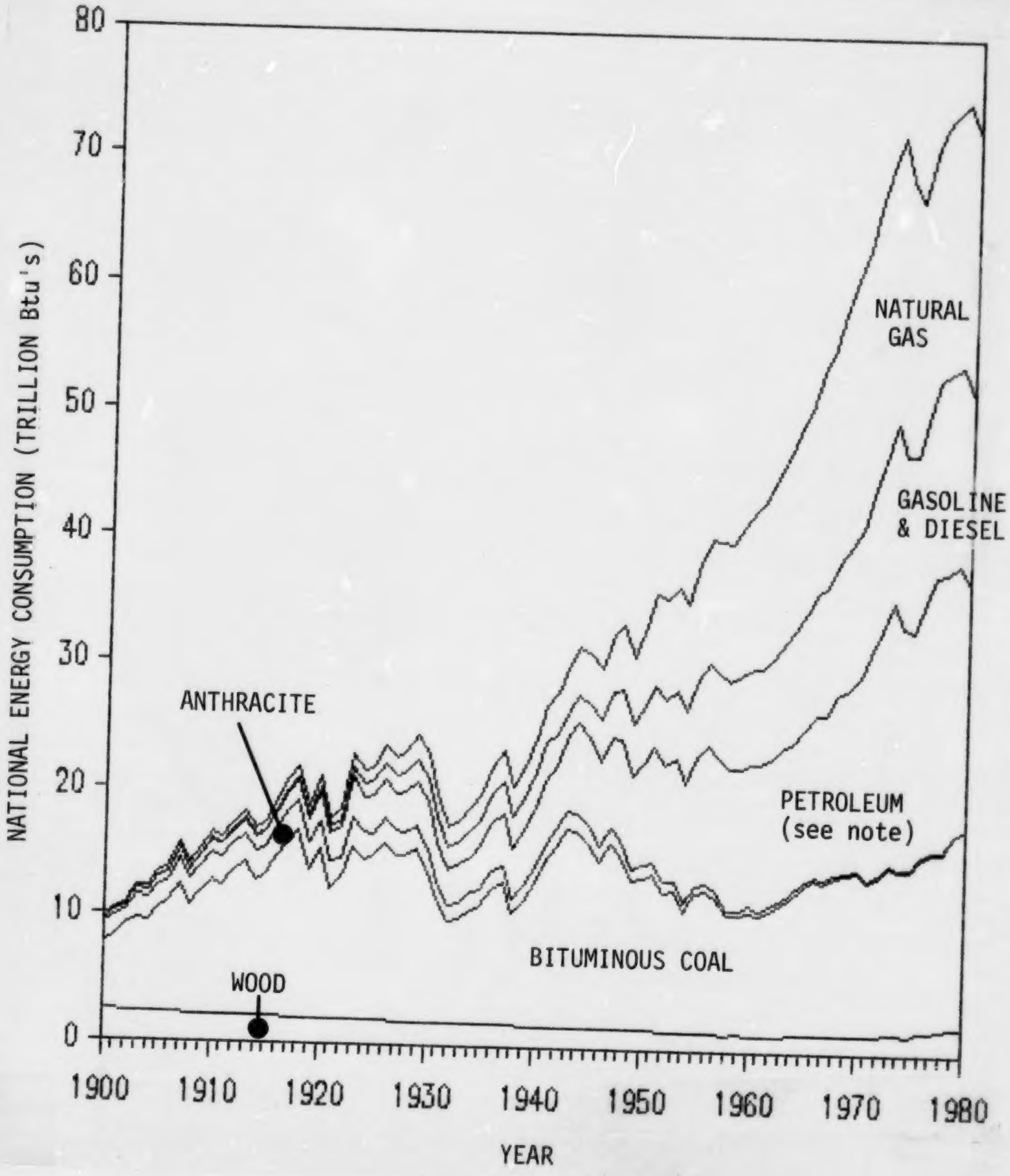

Figure 1. Total mineral fuel consumption of the United States by major source: 1900 to 1980.

(Note: The numerical form of the data is provided in Volume I, Appendix A. Also, the petroleum category shown in the figure includes crude petroleum and petroleum products as consumed, minus the consumption of gasoline and diesel fuel which is shown separately. 1 Btu = 1.055 kJ)

Since 1960, coal consumption has steadily increased on the national level by 30 percent. Crude petroleum and natural gas consumption (the primary sources of NO_x emissions) have increased most rapidly since the 1930's. Wood and anthracite accounted for a large portion of the total energy consumption in the early part of the century but not in the latter part. Until 1930, per capita energy consumption remained nearly constant, declined during the Great Depression and has increased since, except during the oil shortage in the mid-1970's.

3.2 SO_2 Emissions, Overall and for Categories

Figure 2 shows a plot of the total quantity of SO_2 emissions for the contiguous United States by fuel type and for each study year. (It should be noted that the emission levels for consecutive study years are interconnected only to highlight the historic trend. They do not necessarily represent the trends between study years.) Overall, the SO_2 trend follows the general trend of coal consumption except that total emissions appear to have decreased by 10 percent from a maximum around 1970. This decrease is somewhat due to the general decrease in sulfur content of fuels and emission reductions brought about by national and state environmental control regulations.[28] Sulfur content has decreased to a large extent as a result of coal cleaning and mixing eastern coal with cleaner western coal while in the early years coal was mostly burned as received from the nearest coal-producing district.

Figure 3 shows the overall trend by source category. This plot reflects the growth of major fuel-consuming sectors and changes in fuel demand. For example, electric utility emissions appear to have increased sharply by the 1950's and 60's. In contrast, SO_2 emissions from steam locomotives almost completely disappeared by 1950 with the advent of diesel-powered railroads.

3.3 NO_x Emissions, Overall and for Categories

In contrast to SO_2, total NO_x emissions appear to have increased constantly throughout most of the study period as shown in Figure 4. The total quantity of emissions is plotted on the same scale as SO_2 to allow a direct comparison. This upward trend is primarily a result of greater use of natural gas and petroleum products and a conversion away from coal. Figure 5 shows that the increase is largely due to the

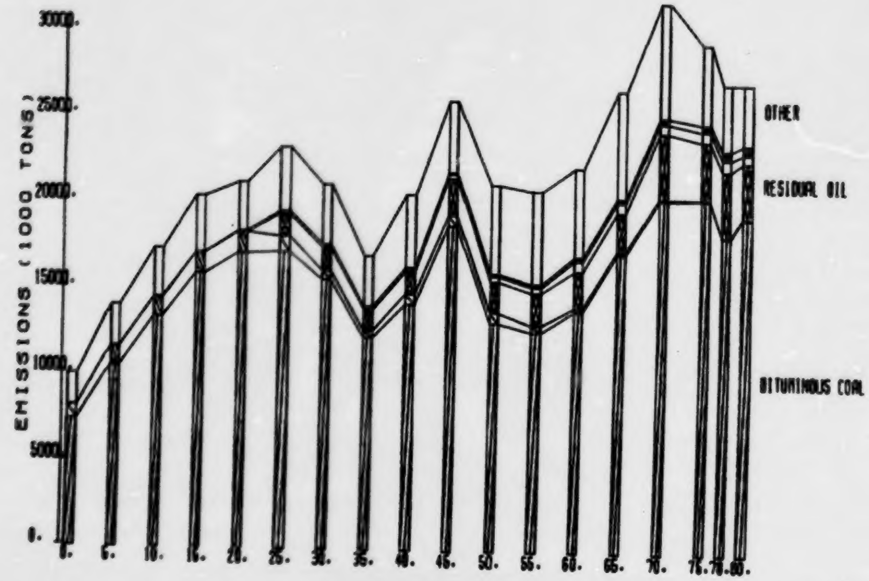

Figure 2. Overall trend in SO_2 emissions from 1900 to 1980 for the United States and by fuel type for each study year.

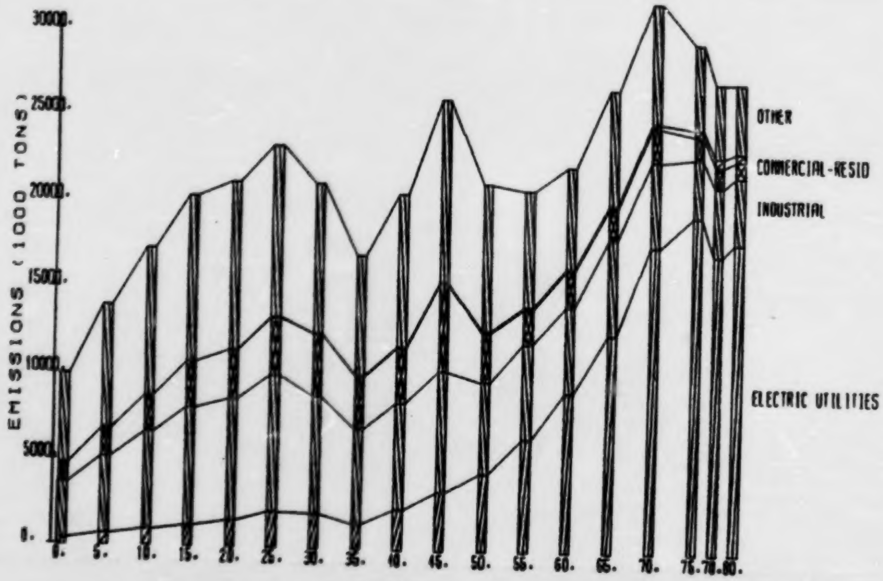

Figure 3. Overall trend in SO_2 emissions from 1900 to 1980 for the United States and by source category for each study year.

Note: The bars in these figures are interconnected only to highlight the overall trend. (**1 ton = 906.18 kilograms**)

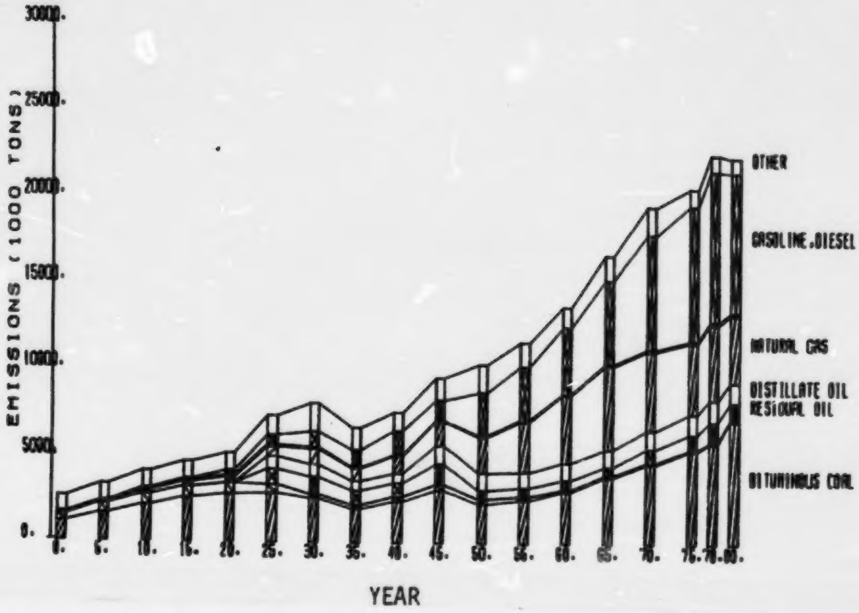

Figure 4. Overall trend in NO_x emissions from 1900 to 1980 for the United States and by fuel type for each study year.

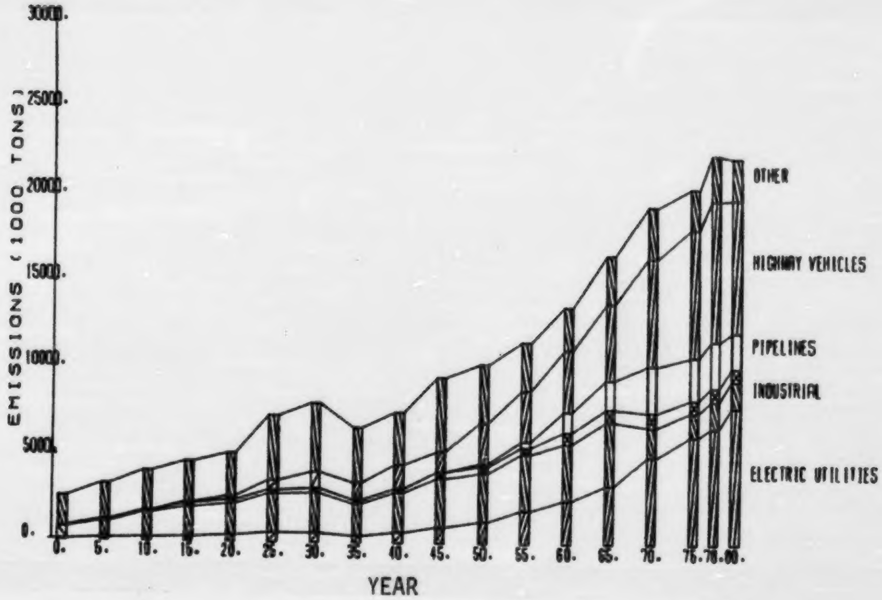

Figure 5. Overall trend in NO_x emissions from 1900 to 1980 for the United States and by source category for each study year.

Note: The bars in these figures are interconnected only to highlight the overall trend. (1 ton = 906.18 kilograms)

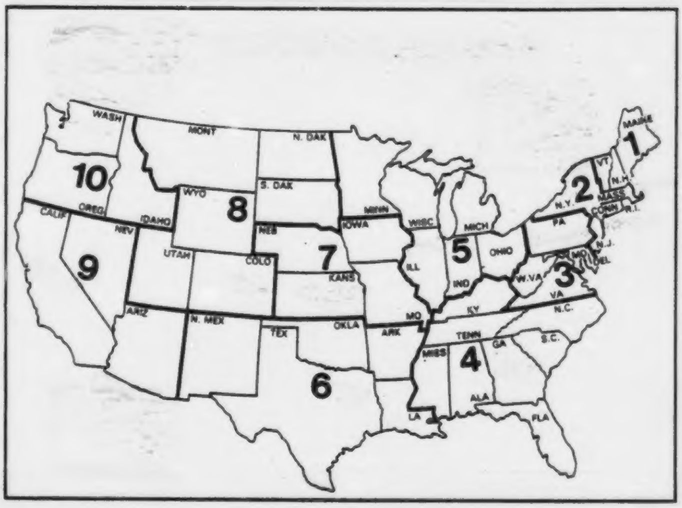
WASH
MONT
N. DAK
MAINE
1
VT
N.H.
10
S. DAK
2
MASS
WYO
8
N.Y.
CONN
R.I.
OREG
CALIF
IDAHO
MINN
WISC
MICH
PA
NEV
NEB
IOWA
N.J.
UTAH
COLO
7
5
OHIO
MD
DEL
9
KANS
ILL
W.VA
3
IND
VA
ARIZ
N. MEX
MO
KY
N.C.
TEX
OKLA
ARK
TENN
S.C.
MISS
4
GA
6
ALA
LA
FLA

Figure 6. Map of the EPA Administrative Regions
(Note: This study does not include Alaska, Hawaii nor territories of the United States.)

growth in the number of highway vehicles, natural gas-fired power plants and many other sources related to a large extent to a growth in population and changes in technology and lifestyles.

4.0 ANALYSIS BY REGION

The total state emissions were aggregated according to the Administrative Regions of the U.S. Environmental Protection Agency shown in Figure 6. These regions represent various broad geographic regions of the country. It should be noted that the regions vary in size and in the number of states and that these two factors will also affect the total regional emissions. By selecting a different combination of states other than these Federal regions, different emission trends may be shown. Recognizing this fact, the regions were selected to provide only a general indication of trends in various regions of the country.

The overall emission trend of each pollutant and the trend by category are plotted in Figure 7 for each region. These plots provide resolution of the national trend and allow the historic emission trends of each region to be compared. For example, Regions 3, 4 and 5 appear to have historically emitted more SO_2 than other regions in terms of total quantity. The total SO_2 emissions of Regions 1 and 2 combined have historically remained constant. In Region 6, NO_x emissions have increased more rapidly than in any other region due to the growth in the natural gas production industry and the number of pipeline compression stations. In all other regions, highway vehicles and electric utilities together have accounted for more than half the total NO_x in the past several decades.

In 1950, the regions east of the Mississippi River emitted 75 percent of the total national SO_2 emissions and 67 percent of the total NO_x emissions. In 1980, the eastern regions emitted 77 percent of the total SO_2 and 60 percent of the total NO_x. During this time period, total national SO_2 emissions increased 140 percent while total NO_x emissions increased 280 percent, or twice as much. While most of the emissions have historically originated in the east, the western regions have begun to emit a greater share of the total national NO_x in recent years.

5.0 ANALYSIS BY STATE

Figure 8 shows graphically the total emission level of each state for every tenth year since 1900. The totals were obtained by aggregating the emissions of all source categories on the state level. The figure provides a general indication of the emission trend in each state and is useful for comparing one state to another. Generally, the figure shows that SO_2 emissions have historically been the greatest in the northeast, especially in the heavily industrialized states. The predominant emitters have been Illinois, Ohio, Pennsylvania and New York, among others, but the emissions have significantly increased in other states, especially those in the southeast and mid-Atlantic region. NO_x emissions have historically increased in all states, especially in those undergoing a rapid economic and population growth. The total state emissions are numerically presented in Appendix A. The emission estimates for each source category comprising the total state emissions are presented in Volume II of this series.[12]

6.0 ANALYSIS BY EMISSION RELEASE (STACK) HEIGHT

Analysis of emissions by release height (actual stack height) is important to studying the potential for long-range transport. The total national emissions associated with four ranges of emission release height are presented in Appendix C. It should be noted that the potential for long-range transport increases with each higher range. This analysis does not include stack exit velocities nor atmospheric mixing heights which are also important considerations. The analysis in this study suggests that more SO_2 emissions were released into the atmosphere from stacks above 240 feet* than from stacks below this height since about 1945. By 1980, approximately 30 percent of the SO_2 emissions were emitted above 480 feet, for example, compared to only 5 percent above this height in 1950. Not only have the percentages increased, but total national SO_2 emissions also increased and peaked around 1970. The percentage of the total SO_2 emissions released below 120 feet has generally decreased over the study period. The distribution of NO_x emissions has historically remained constant, although on the national level the total emissions have steadily increased. Approximately 60 percent of the total NO_x emissions in 1980 were released from ground level sources; predominantly from transportation sources.

(*) 1 foot = 0.3048 meter

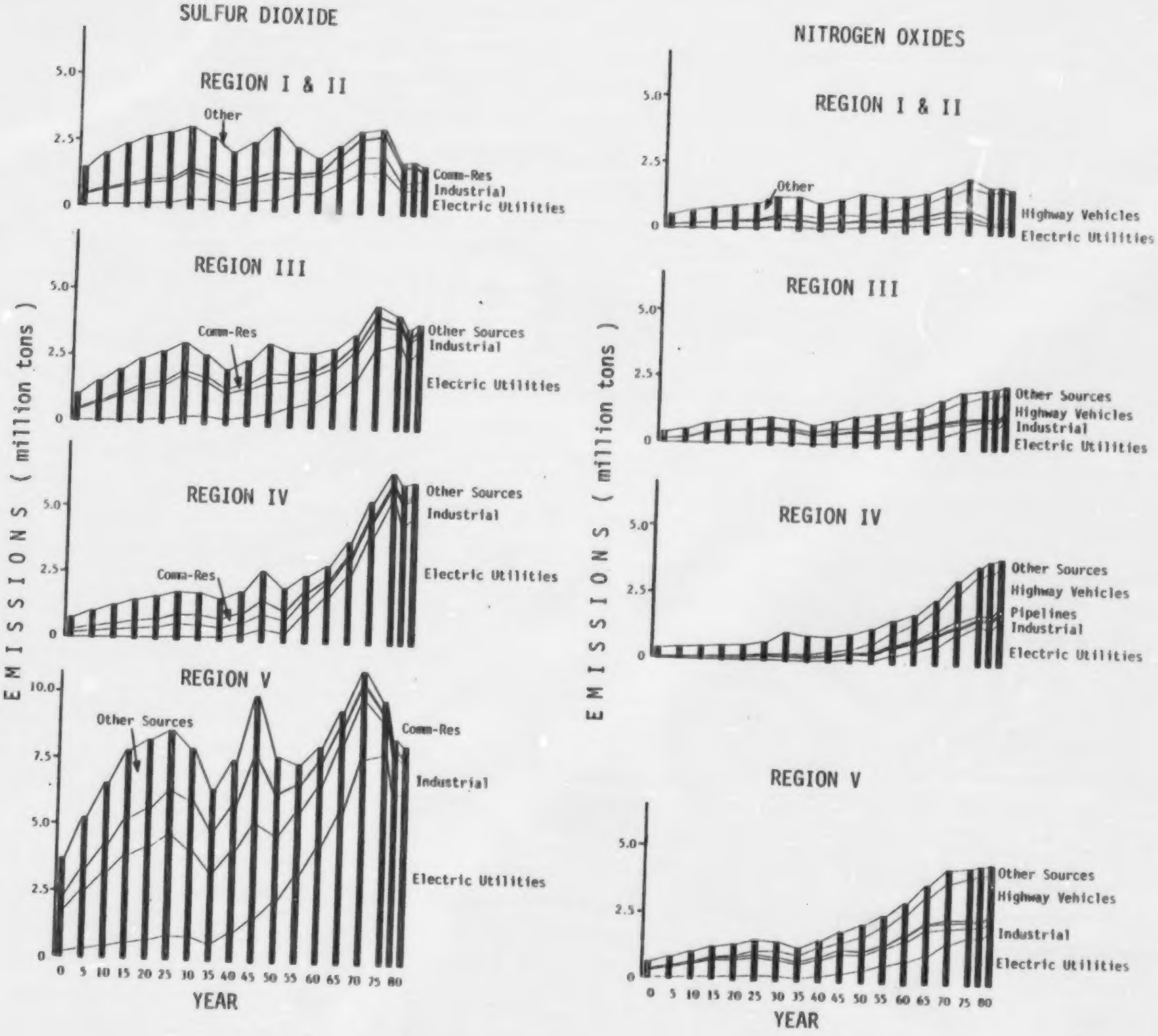

Figure 7 continued opposite page.

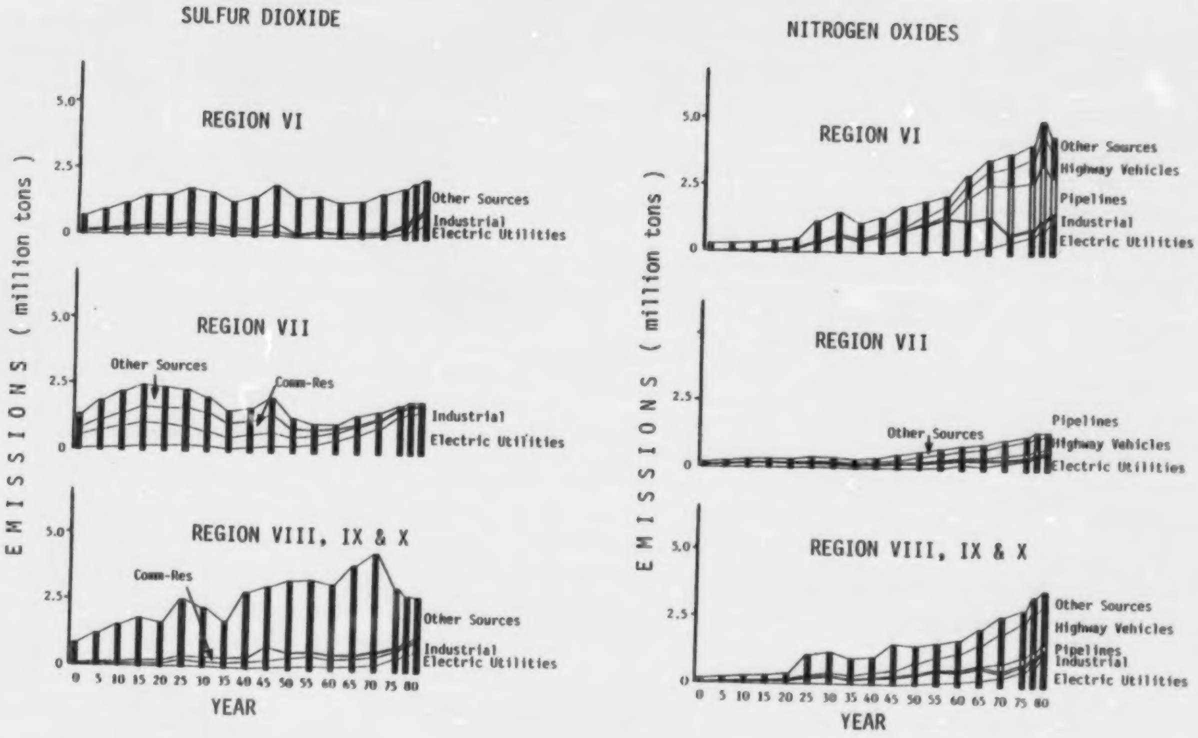

Figure 7. Temporal changes in regional SO_2 and NO_x emissions by source category from 1900 to 1980. (Note: Emission estimates for years prior to 1950 may not account for all emissions due to incomplete data. Refer to Volume II for details on the state level. The category "other sources" includes railroads, vessels, off-highway diesels, wildfires, smelters, and miscellaneous. **1 ton = 906.18 kilograms**)

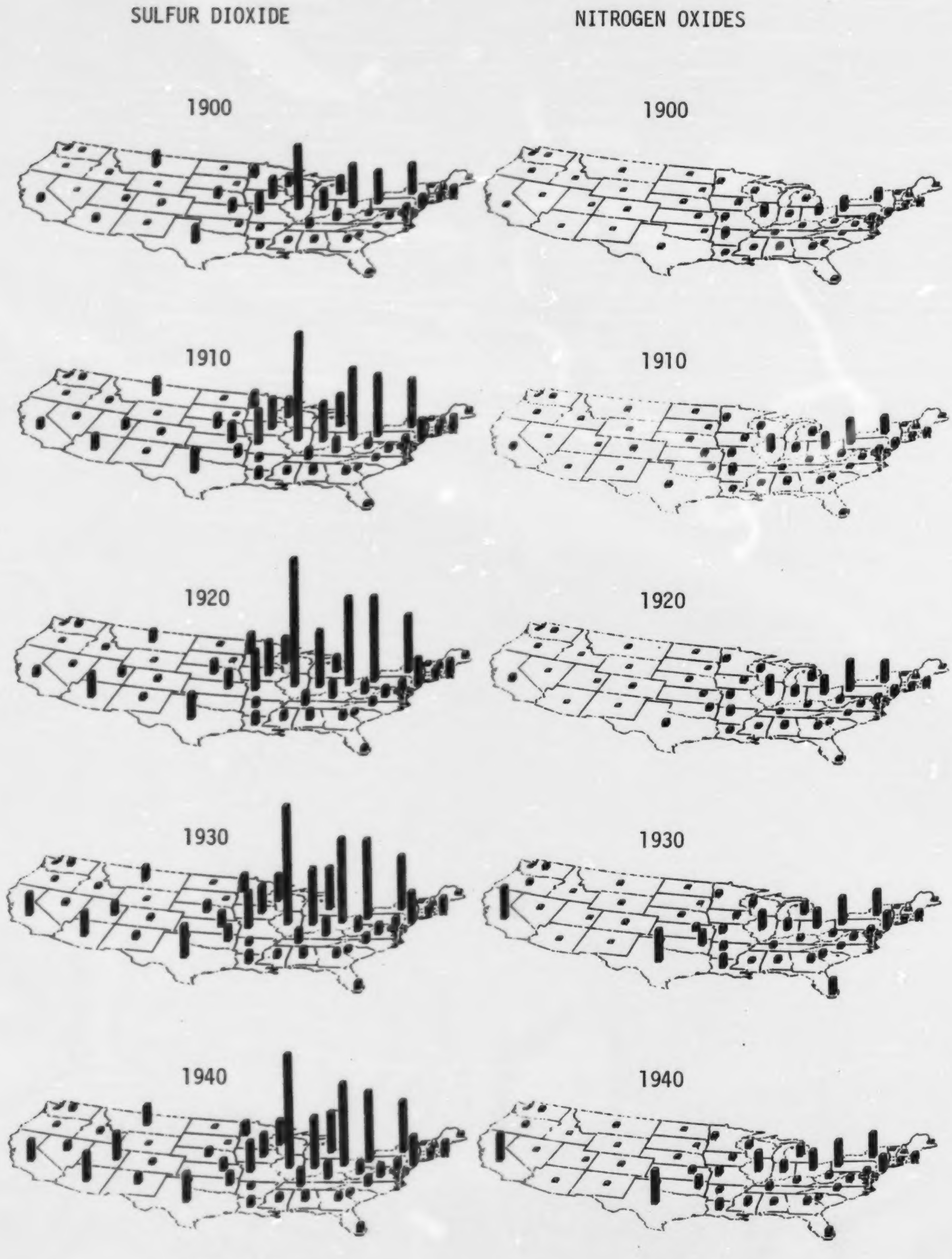
SULFUR DIOXIDE
NITROGEN OXIDES
1900
1900
1910
1910
1920
1920
1930
1930
1940
1940

Figure 8. Continued

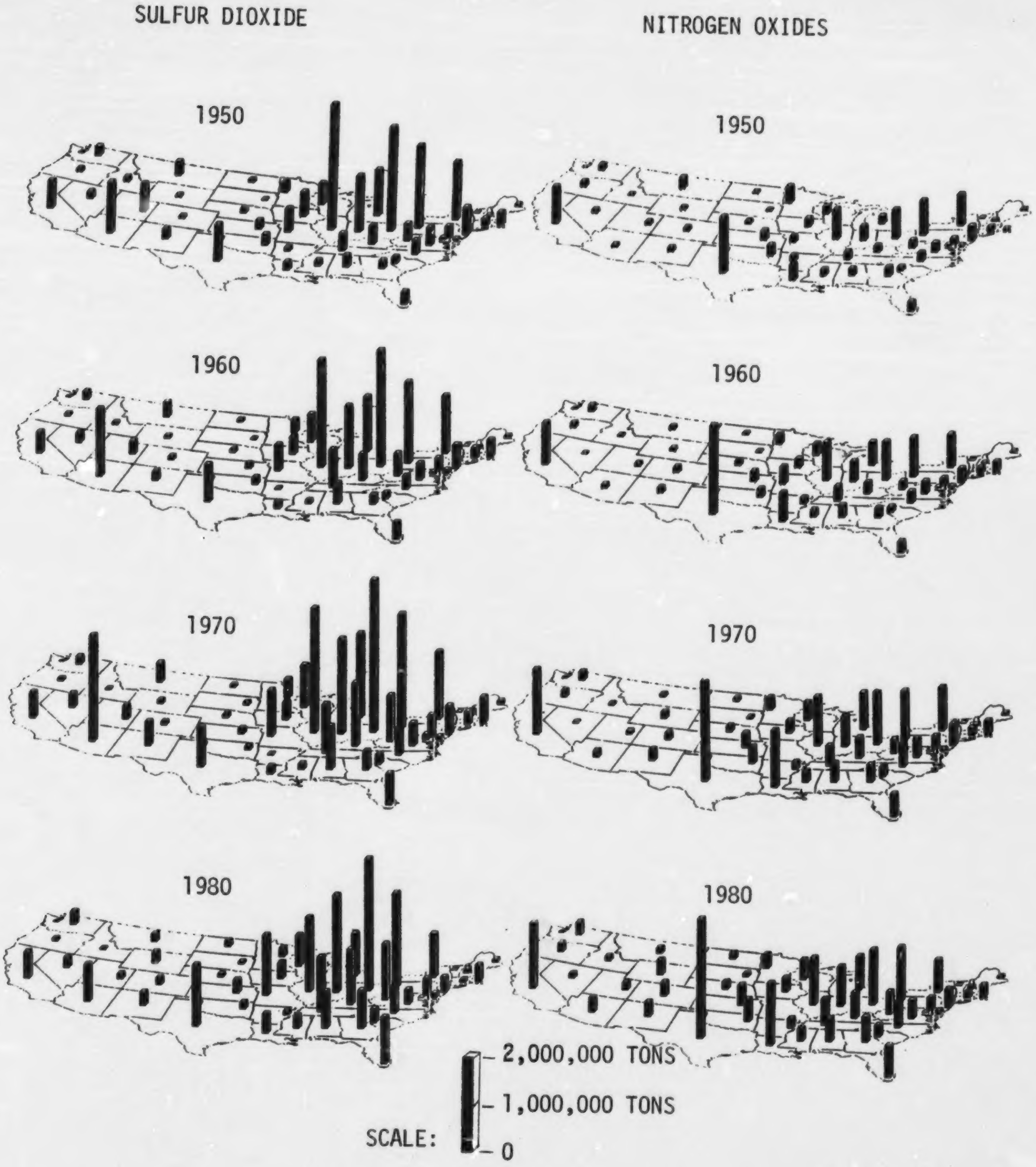
SULFUR DIOXIDE
NITROGEN OXIDES
1950
1950
1960
1960
1970
1970
1980
1980
SCALE:
- 2,000,000 TONS
- 1,000,000 TONS
- 0

Figure 8. Total state emissions of SO_2 and NO_x for every tenth year from 1900 to 1980. (Refer to Appendix A, Volume I for the numerical form of the data shown in this figure. 1 ton = 906.18 kilograms)

Analysis of the electric utility category suggests that in the 1950's and 60's, most of the SO_2 and NO_x emissions from this category were released below 480 feet - mostly between 240 to 480 feet. By 1980, about 50 percent of the total SO_2 emissions and 40 percent of the NO_x emissions from this source category were released above 480 feet as a result of the trend towards taller stacks. Since the emissions from electric utilities constitute a large portion of the total national emissions in recent years as shown in previous figures, they have a significant effect on the overall distribution of emissions by release height.

7.0 DISCUSSION

This chapter has described the basic approach used to develop historic emission estimates for SO_2 and NO_x on the state level. The emissions were derived for individual source categories which collectively account for all manmade emissions. It has presented the trends in total emissions for the contiguous United States, for sub-regions and for individual states. The spatial and temporal trends were shown in five-year iterations. The emission trends of both pollutants vary according to the quantities and types of fuel used and the types of combustion sources. To varying degrees, the trend in emissions has been affected by a growth in population, the level of industrialization, the availability of fuels, and changes in the use of fuels. The trend of SO_2 emissions has also been affected by trends in the sulfur content of coals and oils consumed, especially during the past decade.

When comparing the trend of one state to another or one region to another, it must be remembered that the emission estimates do not represent emission density. (Emission density refers to the total state emissions divided by the area of the state.) Large states may have the highest total emissions but this does not necessarily mean that smaller states do not have the same or even higher emission densities. For example, Illinois, Ohio, Pennsylvania and New York have historically had the greatest SO_2 emissions of all states, but at various times their emission densities were comparable to many other smaller states such as Delaware, New Jersey, and Kentucky among others.

The historic emission estimates derived by this study are consistent in methodology from state to state and from year to year. These state-level estimates may provide sufficient spatial resolution to determine a general relationship between emissions and observed environmental effects. The estimates provide a basis for studies of tree-ring growth patterns, material damage and erosion, and aquatic effects presently underway as part of the National Acid Precipitation Assessment Program. In other studies, Hidy, et. al. investigated the relationship between the SO_2 emission trends on a regional scale and historic deposition monitoring data.[29,30] In another study, Smith, et. al. investigated the relationship between historic emissions and stream chemistry data collected at various sites throughout the country.[31] The historic emission estimates also provide a basis for studying the implications for public policy regarding acid rain.[32] The present emission data file represents the best estimates to date on the state level. As research continues, further refinements in the methodology can be made.

Further improvements would involve completing the data bases on state fuel consumption and sulfur content values for the earlier years and development of state-specific emission factors. However, the greatest obstacle to further improvement is the lack of information. Based on the findings of an extensive literature search during this study, it is unlikely that any additional state-specific data can be obtained. The completion of the data base will require that additional assumptions be made regarding unavailable data.

The aggregated state emissions derived by this study were compared to the national total emissions reported by the U.S. Environmental Protection Agency[5] and the total state emissions of electric utilities estimated by Pechan, et. al.[25] The comparisons indicate close agreement with these other estimates for all common years. The aggregated state totals are within 5.8 percent of the total national emissions estimated by the U.S. Environmental Protection Agency. The aggregated emissions of electric utilities are within 8.4 percent of the estimates by Pechan, et. al. These differences are due to differences in methodology, calculation procedures and numerical round-off. The close agreement adds some reassurance to the historic emission estimates.

Estimates of the probable errors associated with the total state emissions will be based on the results of the uncertainty analysis presently being planned for the 1980 NAPAP emission inventory.[23] The percentage difference between this inventory and the historic emission estimates is 5.9 percent. When the uncertainty analysis of the NAPAP emission inventory is completed, it will serve as a benchmark from which the probable errors of historic estimates can be interpreted after adjustment for assumptions in the methodology.

8.0 CONCLUSION

The current historic emissions data file presents the best estimates available on the state level. The emission trends of each state vary over time reflecting changes in a variety of economic and technological factors. While the national and regional scale emissions data provide general indications of trends, it is recommended that the reader refer to the state-specific estimates presented in Volume II for studies concerning the historic relationship between emissions and environmental effects. These emission estimates can serve as the basis for future studies of the relationship between emissions and environmental effects associated with acid precipitation phenomena.

9.0 REFERENCES FOR CHAPTER I

1. Emissions of Sulfur Dioxide and Nitrogen Oxides from 1950 to 1978 in the Eastern United States. Prepared for the U.S. Environmental Protection Agency under Purchase Order No. D5115 by Pacific Environmental Services, Inc., Durham, NC, 1980. (Unpublished)

2. Emissions of Sulfur Dioxide and Nitrogen Oxides from 1950 to 1978 in the Eastern United States: A Breakdown by Power Plant, Volume I and II. Prepared for the U.S. Environmental Protection Agency under Purchase Order No. D 6710NASX by Pacific Environmental Services, Inc., Durham, NC, 1980. (Unpublished)

3. G. Gschwandtner, C.O. Mann, B.C. Jordan, J.C. Bosch. Historic Emissions of Sulfur and Nitrogen Oxides in the Eastern United States by State and County. Paper No. 81-30.1 presented at the 74th Annual Meeting, Air Pollution Control Association, Philadelphia, PA, 1981.

4. G. Gschwandtner, K.C. Gschwandtner, K. Eldridge. Historic Emissions of Sulfur and Nitrogen Oxides in the United States from 1900 to 1980. Draft Report Prepared for the U.S. Environmental Protection Agency under Contract No. 68-02-3311 by Pacific Environmental Services, Inc., Durham, NC, 1983. (Unpublished)

5. National Air Pollutant Emission Estimates 1940-1982. EPA-450/4-83-024 (NTIS PB84-121391/MF), U.S. Environmental Protection Agency, Research Triangle Park, NC, 1984.

6. F.W. Lipfert, E. Kaplan, M. Daum. Statistical Analysis of Relationships Between Precipitation Chemistry and Air Quality in New Hampshire and Precursor Emissions. Paper No. 21-26.6 presented at the 77th Annual Meeting, Air Pollution Control Association, San Francisco, CA, 1984.

7. R.B. Husar, D.E. Patterson, J.M. Holloway, W.E. Wilson, T.G. Ellestad. Trends of Eastern U.S. Haziness Since 1948. In: Proceedings of the Fourth Symposium on Turbulence, Diffusion, and Air Pollution, Am. Met. Soc., Reno, NV, pp. 249-256, 1979.

8. R.B. Husar, J.M. Holloway, D.E. Patterson. Spatial and Temporal Pattern of Eastern U.S. Haziness: A Summary. Atmos. Environ., 15 (15/11): pp. 1919-1928, 1981.

9. R.B. Husar, D.E. Patterson. Regional Scale Air Pollution: Sources and Effects. Ann. N.Y. Acad. Sci., 338: pp. 399-417, 1980.

10. R.B. Husar, J.M. Holloway. Sulfur and Nitrogen over North America. In: Ecological Effects of Acid Deposition. National Swedish Environment Protection Board-Report PM 1636: pp. 95-115, 1983.

11. Volume II. Data.

12. U.S. Department of the Interior, Bureau of Census. Minerals Yearbook. Washington, D.C., Government Printing Office, Annual.

13. American Petroleum Institute. Petroleum Facts and Figures. Washington, D.C., 1971 Edition.

14. U.S. Department of Energy, Energy Information Administration. Energy Data Report. Series available from U.S. Government Printing Office, Washington, D.C., Annual from 1977.

15. National Coal Association. Steam Electric Plant Fuel Consumption and Costs. Washington, D.C, Annual from 1950.

16. U.S. Department of Agriculture, Forest Service. Wildfire Statistics. Washington, D.C., Annual from 1911.

17. U.S. Environmental Protection Agency. Compilation of Air Pollutant Emission Factors. AP-42 Third Edition (NTIS PB-275525), Supplements 1-7 and 8-14, Research Triangle Park, NC.

18. U.S. Environmental Protection Agency. Mobile Source Emission Factors. EPA-400/9-78-005 (NTIS PB295672/A17), Washington, D.C., 1978.

19. U.S. Department of Energy, Office of Environmental Analysis. NO_x Information Book. DOE/NNB-0044, Washington, D.C., 1983.

20. U.S. Department of the Interior, Bureau of Mines. Sulfur Content of United States Coals. Information Circular 8312, Washington, D.C., 1966.

21. U.S. Department of the Interior, Bureau of Mines. Mineral Industry Survey. Bituminous Coal and Lignite Distribution - Calendar Year 1957. Washington, D.C., 1958.

22. 1955 Keystone Coal Buyers Manual. Carl J. Coash (Publisher), McGraw-Hill Publishing Co. Inc., New York, NY: pp 277-327 and 431-682.

23. U.S. Environmental Protection Agency. Status Report on the Development of the NAPAP Emission Inventory for the 1980 Base Year and Summary of Preliminary Data. EPA-600/7-84-091, Research Triangle Park, NC, December 1984.

24. Estimates of Sulfur Oxide Emissions from the Electric Utility Industry Volume I - Summary and Analysis. EPA-600/7-82-061 (NTIS PB83-130229), U.S. Environmental Protection Agency, Washington, D.C., 1983.

25. E.H. Pechan, J.H. Wilson, Jr. Estimates of 1973-1982 Sulfur Oxide Emissions from Electric Utilities. J. Air Pol. Control Assoc., 34 (10): pp. 1075-1078, 1984.

26. U.S. Bureau of Census. Statistical Abstract of the United States: 1982-83 (103 edition). Washington, D.C., 1982.

27. U.S. Bureau of Census. Historical Statistics of the United States, Colonial Times to 1970, Bicentennial Edition, Part 2. Washington, D.C., 1975.

28. Analysis of State and Federal Sulfur Dioxide Emission Regulations for Combustion Sources. EPA-450/2-81-079 (NTIS PB83-179838/A07), U.S. Environmental Protection Agency, Research Triangle Park, NC, 1981.

29. Analysis of Trends in Historical Acid Precursor Emissions and their Airborne and Precipitation Products. Document No. P-B538 Prepared for the Peabody Coal Company, St. Louis, MO by Environmental Research & Technology, Inc., Westlake Village, CA, 1983.

30. G.M. Hidy, D.A. Hansen, R.C. Henry, K. Ganesan, J. Collins. Trends in Historical Acid Precursor Emissions and Their Airborne and Precipitation Products. J. of Air Pol. Control Assoc., 31 (4): pp. 333-354, 1984.

31. R.A. Smith and R.B. Alexander. Evidence of Acid-Precipitation-Induced Trends in Stream Chemistry at Hydrologic Bench-Mark Stations, U.S. Geological Survey Circular 910, 1983.

32. Acid Rain and Transported Air Pollutants: Implications for Public Policy. U.S. Congress, Office of Technology Assessment, OTA-O-204, Washington, D.C., 1984.

CHAPTER II

METHOD OF DATA PRODUCTION

This chapter presents detailed information on how the emission estimates were derived for each source category. First the source categories are defined and the sources of information on fuel consumption, fuel sulfur content and emission factors are identified. Then the method of data production is described for each source category. Included in this chapter is a discussion of quality control procedures and a comparison of the emission estimates with other available estimates. Methods for further improving the historic emission estimates are also described.

1.0 DEFINITION OF SOURCE CATEGORIES

The definition of each source category is given in Table 2. The definition for each source category was the same for all years with only some minor deviations from the definition for some years. For example, the industrial category from 1970 through 1980 does not include natural gas used in lease operations as gas processing plant fuel. Instead this source is included under the pipelines category for these years. This and other exceptions are noted in the fuel consumption tables contained at the end of Section 1.0 of Volume II. Most deviations from the definitions resulted from changes in data reporting procedures in the references. However, they have a negligible effect on the total emission estimates at the state level.

2.0 SOURCES OF DATA

Relevant data were collected from publications and files of the institutions and Governmental agencies listed below:

American Petroleum Institute
Federal Power Commission
National Coal Association
U.S. Department of Commerce, Bureau of Census
U.S. Department of Agriculture, Forest Service
U.S. Department of Energy
U.S. Department of the Interior, Bureau of Mines
U.S. Department of Transportation, Federal Highway Administration
U.S. Environmental Protection Agency
U.S. Geological Survey

TABLE 2. DEFINITION OF SOURCE CATEGORIES

Electric Utilities	Power plants using coal, oil or gas to produce electricity for public consumption.
Industrial Boilers	Manufacturing and mining establishments which use fuel for heat, power and chemical feedstock, and natural gas lease and plant operations.
Commercial	Nonmanufacturing organizations such as hotels, restaurants, retail stores, laundries, and other enterprises which use fuel and agricultural, forestry and fisheries establishments which use gas.
Residential	Private dwellings, including apartments which use fuel for heating, cooking, water heating, and other household uses.
Pipelines	Transportation of natural gas by compression through pipelines. Internal combustion engines and turbines are used to compress the gas.
Highway Vehicles	Automobile, light duty trucks and motorcycles which require gasoline and trucks, buses and automobiles which require diesel fuel and are used in transportation or public roads.
Railroads	Trains, operated railroad equipment, space heating of buildings, and other related operations.
Coke Plants	Furnace and merchant plants which produce coke.
Smelters	Primary copper, lead and zinc smelting facilities.
Vessels	Commercial or private boats, such as pleasure craft, fishing boats, tugboats and ocean-going vessels including vessels operated by oil companies.
Off Highway Diesel	Engines used in construction, logging and road building equipment.
Cement Plants	Portland cement manufacturing plants.
Wildfires	Protected and unprotected forest land burned.
Miscellaneous	A catch-all category including all industrial processes not included above and all other miscellaneous anthropogenic sources.

The specific publications that were used are identified in the following sections.

2.1 Salient Fuel Statistics

The references for state-level fuel consumption data from 1950 to 1980 are identified in Table 3 for each source category. The table also shows whether the reference reported actual consumption or an indicator of consumption such as fuel demand, distribution, sales or deliveries. An indicator was used whenever actual fuel consumption was not reported. The Energy Statistics Branch of the U.S. Department of Energy (DOE) has adjusted some of these data by various means so that the data more closely reflect actual state consumption. The data are reported annually in State Energy Data Reports which are available beginning with the year 1960.[59] Since 1960 is the earliest year for which DOE data are available, it was decided to use the original data sources for all study years in order to maintain continuity in the emission trend. For most source categories, especially the larger ones, there is little or no difference on a percentage basis between the DOE values for fuel consumption and those used in this study. The percentage difference is usually greater for the smaller source categories. The difference in the total state emissions that could occur as a result of using one set of data or the other, is estimated to be less than 6 percent for either pollutant for any year between 1960 and 1980. To avoid introducing a discontinuity of 6 percent in the emission trend around 1960, the original unadjusted data from the Minerals Yearbook were used instead.

For the time period from 1900 to 1945, the references for the state fuel consumption data are presented in Table 4. Again, fuel consumption was not always reported as is noted in this table. However, state-level data could be interpolated from national fuel consumption data which are available for most source categories. Fuel consumption was estimated by multiplying the reported national consumption by the ratio of the state to national consumption available for the earliest study year. The national consumption values that were used for this procedure are shown in Table 5. This procedure was also used by Husar to obtain state coal consumption by category and who provided these results for inclusion in this study. For electric utilities,

TABLE 3. REFERENCES FOR STATE LEVEL FUEL CONSUMPTION DATA, 1950-1980

Source Category	YEAR							
	1950	1955	1960	1965	1970	1975	1978	1980
	Reference Number							
Bituminous Coal								
Electric Utilities	46	55	42[a]	42[a]	35[b]	36[b]	43[b]	58[b]
Industrial Boilers	47[b],63	47[b]	42[a]	42[a]	35[b]	36[b]	43[b]	58[b]
Commercial-Residential	47[b],63	47[b]	42[a]	42[a]	35[b]	36[b]	43[b]	58[b]
Anthracite Coal								
Total Shipments	37	33	42	42	59	59	59,60	58
Residual Oil								
Electric Utilities	49[c]	49[c]	41[a]	41[a]	39[c]	39[c]	44[c]	56[d]
Industrial Boilers	49[c]	49[c]	41[a]	41[a]	39[c]	39[c]	44[c]	56[d]
Commercial-Residential	49[c]	49[c]	41[a]	41[a]	39[c]	39[c]	44[c]	56[d]
Distillate Oil								
Electric Utilities	48[c]	48[c]	41[a]	41[a]	39[c]	39[c]	44[c]	56[d]
Industrial Boilers	48[c]	48[c]	41[a]	41[a]	39[c]	39[c]	44[c]	56[d]
Commercial-Residential	48[c]	48[c]	41[a]	41[a]	39[c]	39[c]	44[c]	56[d]
Natural Gas								
Electric Utilities	34	33	40[a]	40[a]	38	38	45	57
Industrial	34	33	40[a]	40[a]	38	38	45	57
Pipelines	34	33	40[a]	40[a]	38	38	45	57
Commercial-Residential	34	33	40[a]	40[a]	38	38	45	57
Wood								
All Uses	64	64	64	64	64	64	64	64
Highway Vehicles								
Gasoline	54	54	54	54	e	e	e	e
Diesel Fuel	48,49	48,49	48,49	48,49	39[c]	39[c]	44[c]	56[d]
Rural Vehicle Miles Travelled	f	f	f	f	50	51	52	53
Urban Vehicle Miles Travelled	f	f	f	f	50	51	52	53
Other								
Railroads - Coal	71	71	71	71	71	71	71	71
- Oil	48,49	48,49	48,49	48,49	39[c]	39[c]	44[c]	56[d]
Coke Plants	61	62	42[a]	42[a]	39[b]	36[b]	43[b]	58[d]
Vessels - Distillate	48[c]	48[c]	48[c]	48[c]	39[c]	39[c]	44[c]	56[d]
- Residual	49[c]	49[c]	49[c]	49[c]	39[c]	39[d]	44[c]	56[d]
Off-Highway Diesel	48,49[c]	48[c]	48[c]	48[c]	39[c]	39[c]	44[c]	56[d]
Cement Plants	66	66	66	66,68	66,67	66,67	66,67	66,67
Wildfires	117	117	117	117	117	117	117	117

[a] Reports annual fuel demand.

[b] Reports annual fuel distribution.

[c] Reports annual sales.

[d] Reports annual fuel deliveries.

[e] Emission estimates were based on vehicle miles travelled.

[f] Not available. Instead, actual gasoline consumption was used.

TABLE 4. REFERENCES FOR STATE LEVEL FUEL CONSUMPTION DATA, 1900-1945

Source Category	1900	1905	1910	1915	1920	1925	1930	1935	1940	1945
	Reference Number									
Bituminous Coal										
All categories	69	69	69	69	69	69	69	69	69	69
Anthracite	NA	NA	NA	70	NA	NA	NA	NA	71	72
Residual Oil										
All categories	NA	NA	NA	NA	NA	NA	NA	45	45	45
Distillate Oil										
All categories	NA	NA	NA	NA	NA	NA	NA	44	44	44
Natural Gas										
Electric Utilities	NA	NA	NA	NA	NA	NA	80	NA	74	75
Industrial	NA	NA	76	77	78	79	80	NA	74	75
Commercial-Residential	NA	NA	76	77	78	79	73	NA	81	82
Highway Vehicles										
Gasoline	NA	NA	NA	NA	54	54	54	54	54	54
Diesel	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Miscellaneous										
Railroad - Coal	69	69	69	69	69	69	69	69	69	69
- Oil	NA	NA	NA	NA	NA	NA	NA	48	48	48
Coke Plants	69	69	69	69	69	69	69	69	69	69
Vessels - Oil	NA	NA	NA	NA	NA	48	48	48	48	48
Cement Plants	83	84	85	86	87	88	89	90	91	92
Wildfires	NA	NA	NA	NA	NA	117	117	117	117	117

NA = Not Available.

Note: State consumption estimates for bituminous coal were provided by Husar. These estimates are based on state coal consumption reported for 1889 in *Report on Mineral Industries in the United States at the Eleventh Census: 1890*, Department of the Interior, Census Office, and for 1917, 1927 and 1957 reported in *Minerals Yearbook*.

TABLE 5. NATIONAL FUEL CONSUMPTION BY SOURCE CATEGORY, 1900-1945

Source Category	YEAR									
	1900	1905	1910	1915	1920	1925	1930	1935	1940	1945
	National Consumption									
Bituminous Coal [a] (1,000 tons)										
Electric Utilities	7,600	14,540	19,798	26,527	33,411	42,541	42,900	30,937	49,126	71,610
Industrial Boilers	67,200	101,790	127,419	153,907	161,827	168,818	141,830	114,637	127,595	145,007
Commercial-Residential	28,100	44,061	57,582	75,965	79,701	90,911	98,563	80,442	84,685	119,300
Anthracite Coal [b] (1,000 tons)	55,515	75,201	81,110	85,033	85,786	64,061	67,628	51,100	49,000	51,600
Residual and Distillate Oil [c] (1,000 bbl)										
Electric Utilities	NA	NA	NA	NA	NA	33,652	26,749	23,647	31,164	38,289
Industrial Boilers	NA	NA	NA	NA	NA	118,037	112,816	111,692	123,688	162,457
Commercial-Residential	NA	NA	NA	NA	NA	36,835	62,572	100,414	191,153	290,892
Natural Gas [a] (10^6 cu.ft.)										
Electric Utilities	NA	NA	NA	NA	22,000	46,000	120,000	125,239	183,156	326,190
Industrial [d]	NA	NA	339,332	412,000	512,000	916,293	NA	1,227,880	1,893,213	3,062,980
Pipelines	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Commercial-Residential	NA	NA	169,823	217,203	286,001	272,146	376,407	310,200	578,290	837,499
Highway Vehicles [e,f]										
Motor Fuel (1,000 gal)	4	35	227	1,164	4,068	8,749	14,754	16,345	22,001	19,149
Wood [b]										
All uses combined (1,000 cords)	100,00	95,000	91,000	87,000	83,000	79,000	75,000	72,000	70,000	65,000
Other										
Railroads -										
- (1,000 tons) Coal[a]	57,200	91,760	115,282	129,037	142,779	118,455	101,899	79,790	88,122	128,317
- (1,000 bbl)- Oil[c]	NA	NA	NA	NA	NA	72,218	67,900	55,651	66,260	114,719
Coke Plants[a]	30,201	41,082	57,841	62,239	75,922	69,860	69,805	50,514	81,384	95,348
Vessels -										
- (1,000 bbl) Oil[c]	NA	NA	NA	NA	NA	79,288	94,131	74,581	61,824	

[a] Reference Mines, Mineral Yearbooks and Geological Survey, Resources of the U.S.

[b] Reference 109, p. 508-509.

[c] Reference 109, p. 113. Includes residual, distillate, and gas oil·but excludes diesel oil and kerosene sold as range oil.

[d] Includes petroleum refineries, portland cement plants, natural gas lease and plant operations, and "other industrial uses."

[e] Reference 54. Includes all highway use of motor fuel. Does not include exports or Federal purchases for military use.

[f] For 1900 to 1920, national fuel consumption is estimated on the basis of automobile registrations. Reference 54, p. 23.

industrial, commercial and residential sources, state coal consumption is reported for 1889, 1917, 1927 and 1957. For railroads it is reported for 1889, 1917, 1937, 1947 and 1960. The ratio of state to national consumption for these years was then multiplied by the national consumption reported for the intervening years.

The categories for which this approach could not be used because national consumption was not reported are listed below.

a. All fuel oil burning categories, 1900 to 1920
b. Natural gas-fired electric utilities, 1900 to 1915
c. Natural gas-fired industrial, commerical and residential categories, 1900 and 1905
d. Pipelines, 1900 to 1945

These categories either did not exist in some states or were so small that records were not kept. For this reason, the exclusion of these categories from the estimations is considered to make little difference to the total emission estimates.

2.2 Fuel Sulfur Content

The sources of state sulfur content data for coal and oil are identified in Table 6. Sulfur content values vary from one state to another depending on the quality of the fuel and in recent years on the state environmental regulations that limit the amount of permissible sulfur content. It was possible to obtain sulfur content values on the state level for most source categories beginning with 1965. For the oil consuming categories, average state sulfur content was derived from samples of heating oil manufactured by domestic refineries and marketed in 16 districts across the United States as reported by the Bartlesville Energy Technology Center. For coal-fired electric utilities, state values were derived from individual power plant data available from the Federal Power Commission. The derivation involved weighting the average sulfur content of individual power plants by the reported annual fuel throughput of each plant on the state level.

For 1955, average state sulfur content was estimated for each coal-consuming category from information on the quality, quantity and distribution of coal. The first step in this procedure involved

TABLE 6. REFERENCES FOR SULFUR CONTENT DATA

Source Category	YEAR 1950	1955	1960	1965	1970	1975	1978	1980
	Reference Number							
Bituminous Coal								
Electric Utilities	a	107,108	b	95	94	94	94	94
Industrial Boilers	a	107,108	b	95	100,101	98,99	98,43	98,43
Commercial-Residential	a	107,108	b	95	100,101	98,99	98,43	98,43
Residual Oil								
Electric Utilities	b	b	b	b	94	94	94	93
Industrial Boilers	a	102	103	104	96	97	105	106
Commercial-Residential	a	102	103	104	96	97	105	106
Distillate Oil								
Electric Utilities	c	c	c	c	c	94	94	93
Industrial Boilers	a	102	103	104	96	97	105	106
Commercial-Residential	a	102	103	104	96	97	105	106
Coke Plants	a	107,108	c	95	100,101	98,99	98	98

[a] Same references and data were used as for 1955.

[b] Same reference and data were used as for 1965.

[c] Sulfur content was assumed to be 0.300% on average for lack of a specific reference.

tabulating the average sulfur content of the coal by coal seam or coal field as reported in the Keystone Coal Industry Manual.[107] Secondly, the quantity of coal shipped from each mining district was noted. In addition, the state of destination and consumer category was noted as reported in the Mineral Yearbook. Then for each state receiving coal, an average sulfur content value could be calculated for each source category. The same procedure was applied to 1965 to compare the results with the values reported by the Bureau of Mines.[95] The results were generally within ±10 percent of the reported values with few exceptions, thus adding some confidence to the 1955 sulfur content estimates. The sulfur content values used in this study are presented in Volume II, Appendix A.

2.3 Emission Factors

The emission factors for the stationary sources originated from the EPA publication entitled, Compilation of Air Pollutant Emission Factors, AP-42, Third Edition.[111] This document contains emission factors for each type of emission source. Periodically, AP-42 is updated to incorporate new or improved emission test data. The emission factors used in this study were current to Supplement No. 14 of AP-42.

The emission factors used in this study were specifically derived to represent the category as a whole. This was done by mathematically weighting the factors reported in AP-42 for each source type according to the total quantity of fuel consumed by each source type. The resulting factors are shown in Volume II, Appendix B.

For the highway vehicles category, emission factors were obtained from the EPA's MOBILE 2 model.[112] The factors are based on the yearly mix of vehicle types, VMT mix, and automobile emission controls. These factors are state-specific and in the case of NO_x, take into account the amount of urban and rural VMT's and VMT's at low and high altitudes as well as several other assumptions.

3.0 CALCULATION PROCEDURE

For each source category, the annual fuel consumption (FC) was multiplied by a representative emission factor (EF) for each pollutant. For SO_2, the emission factor was scaled by the average sulfur content (S) of the fuel consumed by the given category. The calculation procedure can be expressed for most categories by the following equations.

$$SO_2 \text{ Emissions} = FC_{i,j,k} \times [EF_{SO_2} \times S_{i,j,k}] \quad \text{(eq. 1)}$$

$$NO_x \text{ Emissions} = FC_{i,j,k} \times EF_{NO_x} \quad \text{(eq. 2)}$$

where, i = year
j = source category
k = state

In the case of coke plants, cement plants and highway vehicles, the emission factors varied by state. For the highway vehicles category, the calculation can be expressed as follows:

$$\text{Emission}_{i,k} = VMT_{i,k} \ X \ EF_{i,k} \quad \text{(eq. 3)}$$

where, i = year from 1970 to 1980. For earlier years VMT were estimated for each state from state gasoline consumption and an assumed fuel efficiency value.

k = state

The resulting estimates represent uncontrolled emissions except for the highway vehicles category where the emission factors account for the effect of automobile emission controls. For electric utilities and for smelters, the amount of SO_2 controlled was subtracted from the calculated uncontrolled emissions. All other categories, with few exceptions, are considered uncontrolled on a historic basis.

The calculation procedure is described in the following sections for each source category. Any additional assumptions or computations are also discussed.

3.1 Electric Utilities

Annual emissions for this category are a function of the quantity of fuel burned, fuel quality and controls applied to the fuel-based emissions. The quantity of fuels burned implicitly accounts for the capacity utilization of power plants. The quantity of fuel burned was assumed to be equal to either the quantity distributed, demanded, or sold to power plants whenever actual fuel consumption was not available (as is noted in Table 5). This assumption was necessary because it is unknown how much coal was left over from one year to the next. The assumption, however, has little effect on the long term trend of emissions.

For the period 1970 to 1980, average state sulfur content was calculated using average sulfur content values reported for individual power plants.[93,94] These values were weighted by the fuel throughput of individual plants on the state level. For 1965, the average state values for coal-fired electric utilities were obtained from the Minerals Yearbook,[95] and for 1955, were calculated as described in Section 2.2 of this chapter.

National SO_2 and NO_x emission factors were used for coal-fired and for oil-fired power plants. Since the formation of NO_x is highly dependent on boiler type and firing configuration, the average emission factor was based on the reported generating capacity of the various boiler types, assuming that generating capacity was proportional to fuel throughput. The boiler types vary depending on the source category. For example, boiler types used in the electric utility source category include pulverized coal-fired, cyclone, spreader stoker, and tangentially-fired and other boiler types. For SO_2, the emission factor for coal-fired power plants was weighted by the quantity of bituminous and subbituminous coal and lignite burned. This weighting was based on the information contained in the National Emissions Data System (NEDS) for the years 1975, 1978 and 1980, and the generation and fuel consumption file, Form 4 of the Federal Power Commission.[121] The same national emission factors derived on the basis of recent fuel throughput data were used for all states regardless of the actual boiler population or coal type used in the state. This assumption may introduce some error in the emission estimates for some states, but does not affect the total national emission estimates.

Uncontrolled emissions were calculated using equations 1 and 2. The total amount of SO_2 removed by FGD systems in each state, shown in Table 7, was then subtracted. The first study year during which FGD systems reduced emissions at power plants was 1975, although at some plants these systems existed as early as 1971.

3.2 Industrial Boilers and Space Heaters

This source category includes all industrial boilers and space heaters that consumed either bituminous coal, residual and distillate oil, natural gas or wood. It also includes the operation of oil drilling equipment and other field or refinery operations.

TABLE 7. POWER PLANT EMISSION REDUCTIONS[a]

State	Emission Reductions (1,000 tons) 1975	1978	1980
Alabama	0	2.2	9.8
Arizona	2.4	5.6	33.7
Colorado	0	0	6.5
Illinois	0	12.9	148.1
Indiana	0	54.7	95.0
Kansas	103.9	68.6	78.1
Kentucky	1.4	36.5	169.7
Minnesota	0	32.4	49.4
Mississippi	0	2.2	12.8
Missouri	7.7	25.1	36.6
Montana	1.4	17.6	20.6
Nevada	5.0	9.5	8.2
New Mexico	0	14.7	42.0
North Dakota	0	10.5	26.3
Ohio	0	89.6	113.6
Pennsylvania	40.7	213.1	325.9
South Carolina	0	6.5	13.6
Texas	0	64.6	134.5
Tennessee	0	34.0	24.0
Utah	0	4.5	23.3
West Virginia	0	0	5.2
Wyoming	0	0	13.1
All Other States	0	0	0
Total	162.5	704.9	1,390.0

---

[a] Data extracted from Reference 110 on a plant by plant basis by Charles O. Mann, National Air Data Branch, U.S. Environmental Protection Agency. The reductions are due to the use of flue gas desulfurization (FGD) by at least one plant in each state. A zero indicates no reduction in the given year because FGD systems had not become operational.

For the oils, sulfur content was reported by domestic oil marketing districts. However, the perimeter of a marketing district did not always border state lines. The states that overlapped two or more marketing districts were divided according to the state area contained in each district. The average sulfur content of different oil grades in each state was then estimated by weighting the reported sulfur content by the area of the state in each marketing district.

For bituminous coal, average sulfur content was derived for 1955 by the method described in Section 2.2 of this chapter. For the other years, an average state value was calculated from the sulfur content reported by district of origin and the reported distribution of coal. This procedure involved weighting the reported sulfur content values according to the amount of coal consumed in each state.

National emission factors for the coal and oil-fired components of this category were established in a manner similar to that of electric utilities. Emissions were calculated using equations 1 and 2. The natural gas-fired industrial source category includes boilers, heaters and also field sources associated with the production of natural gas. Field sources include drilling, pumping and processing operations which primarily used reciprocating engines and turbines. Field sources were included under the industrial category because for certain years the fuel consumption of these sources are not provided separately. This necessitated including them in this category and applying a weighted average emission factor to account for their contribution to the NO_x emissions. It should be noted that for the years 1970 to 1980 these sources are included under pipelines, but for earlier years are included under natural gas-fired industrial.

3.3 Commercial and Residential Uses

The procedure for this source category was similar to the procedure for industrial boilers except that the NO_x emission factor was varied to account for changes in the composition of this category. For 1980, the NO_x emission factor represented an average for both the residential and commercial heater populations, weighted according to the fuel consumption by each group. For earlier years, the factor was adjusted to represent a proportionally greater fuel consumption by the residential sector. For 1950 and prior years, the factor almost entirely represents the residential sector.

3.4 Anthracite - All Uses

This source category represents all uses of anthracite coal combined. The SO_2 emissions for each state were calculated using the following equations.

SO_2 Emissions = Total Shipments X [EF_{SO_2} x 0.8] (eq. 4)

where, 0.8 = average sulfur content expressed as percent weight

EF = emission factor for SO_2

NO_x Emissions = Total Shipments X EF_{NO_x} (eq. 5)

Most references report only total shipments of anthracite to each state and further segregation of consumption according to consuming sector was not possible. An average weighted emission factor was established to represent all anthracite-consuming sectors combined. In the case of anthracite, which originates mostly in Pennsylvania, the chemical composition as mined and as consumed is relatively constant over time, thus allowing one factor to be used for all years. An average sulfur content of 0.8 percent by weight was assumed.

3.5 Pipeline Compression Stations

This source category includes internal combustion engines and turbines used to transport natural gas through pipelines by means of compression. Most compression stations are located in the natural gas producing states. For the years prior to 1970, lease and natural gas plant operations are included in the industrial category. For the years 1970 to 1980, these operations are included in the pipelines category. This difference does not, however, affect the total emissions of the two categories combined.

An average NO_x emission factor was derived for the category by weighting the factors for natural gas-fired reciprocating engines and turbines according to the reported fuel consumption of each. Emissions were than calculated on the basis of fuel consumption reported for the category as a whole.

3.6 Highway Vehicles

This source category includes both gasoline and diesel-powered vehicles. Each was treated separately for the purpose of calculating emissions.

3.6.1 Gasoline-Powered Vehicles

For 1970 to 1980, emission estimates for gasoline-powered motor vehicles were based on vehicle-mile tabulations and state-specific emission factors. Four vehicle categories were considered: light duty gasoline vehicles (passenger automobiles), light duty gasoline trucks (trucks less than 6,000 pounds in weight, and trucks 6,000 to 8,500 pounds in weight), heavy duty gasoline trucks and buses, and motorcycles. The NO_x emission factors were obtained from the MOBILE 2 model developed by EPA to calculate emission factors on an annual basis.[112] The SO_2 emission factors were taken from AP-42.

To derive the NO_x emission factors, assumptions were made regarding vehicle speeds, ambient temperature, vehicle miles traveled (VMT) mix and vehicle mix. These assumptions are shown in Table 8. Only two average vehicle speeds were used. Greater accuracy can be achieved by using more than two vehicle speed categories but this would greatly complicate the emission calculation procedure. The NO_x emission factors were then mathematically weighted to reflect the VMT in low elevation states, high elevation states and in California. For each state, separate NO_x emission factors were derived for urban and rural traffic and NO_x emissions were then calculated using equation 3 for both reported rural and urban VMT. SO_2 emissions were calculated on the basis of total VMT.

For 1965 and earlier years, VMT data were not available on the state level. Instead, emissions were calculated using state fuel consumption, MOBILE 2 emission factors based on reported vehicle mix, and an average national fuel efficiency values shown in Table 9. The percentage of urban and rural VMT were assumed to be the same in each state as for 1970. This is a reasonable assumption considering that on the national level, the ratio of urban to rural VMT remained about the same ($\pm$5 percent) from 1936 to 1970. It is possible to estimate vehicle emissions based on state fuel consumption back to 1925; the earliest year of record. Since NO_x emissions from vehicles were significant in these early years, vehicle emissions were estimated on the basis of vehicle population.

TABLE 8. ASSUMPTIONS REGARDING THE NO_x EMISSION FACTORS FOR HIGHWAY VEHICLES

Variable	Assumptions
Vehicle Speeds:	19.6 mph for urban roads 45.0 mph for rural roads
Annual Ambient Temperature[a]:	57°F for low altitude areas 54°F for high altitude areas 65°F for California
VMT	Same VMT mix by vehicle type for all areas
Vehicle Mix by Model Year:	For each study year, the actual national model year age distribution is used based on vehicle registration records. The same distribution is used for all areas.

---

[a] Since average temperature for individual low elevation states may vary considerably from the national average, some error may be introduced by using a national average value. NO_x emissions for warmer states will be overestimated and emissions for colder states will be underestimated. These errors, however, are considered to be minor, compared to only assuming two-vehicle speeds.

TABLE 9. ASSUMED VALUES FOR MILES PER GALLON

Source: Federal Highway Administration[54]

Year	National Average Miles Per Gallon
1965	12.48
1960	12.44
1955	12.60
1950	12.87
1945	13.40
1940	13.83
1935	13.98
pre 1935	14.0

3.6.2 Diesel-Powered Vehicles

For all the study years, three diesel-powered vehicle categories were considered: light duty vehicles, light duty trucks, and heavy duty vehicles. Calculations are based on reported diesel fuel consumption. It was also decided to use an average national emission factor for SO_2 and one for NO_x to simplify the emission calculation procedure. This is considered a reasonable approach because the emissions from diesel-powered vehicles have been predominantly released by heavy duty vehicles for which there have been no emission standards.

3.7 Railroads

This source category is divided into steam-powered locomotives burning bituminous coal and diesel-powered locomotives. Steam engines using anthracite are included in the anthracite-all uses category discussed in Section 3.4 of this chapter. For both types of railroad engines, the reported state fuel consumption was multiplied by a national average emission factor for each pollutant using equations 1 and 2. On the state level, where there is a mixture of various classes of railroads, the use of an average emission factor is reasonable.

3.8 Coke Plants

Emissions from coke manufacturing originate from the process of heating coal in an atmosphere of low oxygen content. About 67 percent of the total sulfur in the coal charged is emitted by combustion stacks and about 33 percent is transferred to the coke oven gas. The SO_2 stack emissions were calculated using equation 1 on the basis of coal charged at the state level. Average state-level sulfur content of the coal charged was obtained for most of the recent years except for 1955 where it was calculated from individual coke plant data. The state sulfur content values are presented in Appendix A of Volume II. This method accounted for most of the SO_2 emissions from coke plants. The remaining SO_2 emissions transferred to the coke-oven gas and emitted in other parts of steel manufacturing operations, are accounted for in the miscellaneous category. NO_x emissions are comparatively minor, but were calculated using equation 2. All emissions were assumed to be uncontrolled for the purposes of this study.

3.9 Primary Smelters

This source category is composed of primary copper, zinc and lead smelters, whose predominant emissions are SO_2. Estimating emissions from these sources on the national level is straightforward. First uncontrolled emissions are calculated by multiplying the total national production of primary slab by the average emission factor obtained from AP-42. The total SO_2 removed to produce by-product sulfuric acid is then subtracted from the uncontrolled emissions to give an estimate of controlled SO_2 emissions.

On the state level, the emission calculation is complicated by the fact that state production of primary slab is not reported. Instead, the Bureau of Mines reports mine production in terms of recoverable metal for years prior to 1950. This does not necessarily mean that the recoverable metal reported for a state was smelted in the same state. Further complications are created by the lack of information on a plant-by-plant basis of by-product sulfuric acid production. Instead, only the total national quantity of by-product sulfuric acid is reported. As a result, state emissions for each type of smelter were calculated individually on the basis of the following assumptions.

1. Mine output is smelted in the same state if the state was reported to have a primary smelter in operation in the given study year.
2. If the state was not reported to have a primary smelter, it was assumed that mine output was smelted in the nearest state that was reported to have a smelter operating.
3. SO_2 used to produce sulfuric acid is proportional to the estimated smelter state output.

These assumptions applied to the emission estimates for copper smelters prior to 1950 and for most zinc smelters and lead smelters prior to 1960.

For years after 1950, the Bureau of Mines reports the tonnage of copper ore concentrate produced by most smelter states. These tonnages were multiplied by an emission factor of 2 tons SO_2/ton concentrate to yield the estimated SO_2 emissions. This method did not yield estimates for Texas because the quantity of ore concentrate produced there was not reported. For the major copper smelter states of Arizona, Nevada and Utah, the quantity of emissions for the period from 1950 to 1975 was obtained from a study of emissions and visibility.[122] The Arizona copper smelter emissions for 1978 and 1980 were taken from smelter information provided by the U.S. Environmental Protection Agency.[65] For 1980, state emissions for nonferrous smelters was taken from the Work Group 3B report.[113] These estimates also provided a basis for estimating the emissions for 1975 and 1978 by apportionment of the total national emissions. The estimates for zinc and lead smelters after 1960 are based on a study of individual smelters and national production figures.[118] The information used to calculate state-level emissions for this category is presented in Volume II, Appendix C.

3.10 Vessels

This source category is divided into vessels using either diesel fuel or residual oil. The category includes all commercial and private boats and ocean-going vessels that operated in the inner and coastal waterways of the contiguous United States. Gasoline-powered motorboats are included under the miscellaneous category.

The emissions were calculated by multiplying the reported state fuel consumption of each fuel by national average emission factors. For the years 1950 to 1980, AP-42 emission factors for vessels were weighted according to the fuel consumed by each class of vessel. For the earlier years, the factors were weighted mostly by the vessels using residual oil since this was the predominant fuel. These vessels were usually large ocean-going vessels compared to diesel-powered vessels which were smaller vessels or tugboats.

3.11 Off-Highway Diesel Engines

This category includes the diesel engines used in construction, logging and road building. The emissions were calculated by multiplying the reported fuel consumption on the state level by emission factors obtained from NEDS. The emission factors for off-highway diesel engines represent the category as a whole.

3.12 Cement Plants

Emissions of SO_2 and NO_x are products of the coal and oil used to supply heat for the kiln in the manufacture of portland cement. SO_2 is also emitted by the raw minerals feed to the kiln which contains various amounts of sulfur.

The emissions of both pollutants were calculated on the basis of the total quantity of portland cement produced in each state. For SO_2, state average emission factors were calculated. These factors represented the sum of the emission factors for coal and oil combustion and mineral sources. The coal and oil factors were derived on the basis of the type of fuel used at each plant and an approximate quantity based on plant production capacity. For NO_x, a national average emission factor was used. NO_x emissions are much less than the SO_2 emissions from this industry.

3.13 Wildfires

The wildfires category includes any fire that burned uncontrolled in protected or in unprotected lands. Statistics on wildfires, such as the total area of each state burned each year are provided by the U.S. Forest Service.[117] This information is available for all states beginning in 1940 and for most states since 1925. It is not known whether these fires were started by natural causes or by man, but are included in this study anyway. The emissions vary from state to state depending on the size and type of vegetation of each state.

Emissions were estimated for each study year and state, by using total area burned and the appropriate emission factors obtained from AP-42. The factors were state-specific, depending on the fuel loadings which are a function of the general type of vegetation found in each region of the country. The wildfire statistics used in this study are presented in Volume II, Appendix D. Wildfire statistics indicate a general decrease in the total area burned in each state over time, partly as a result of fire prevention programs of the past 40 years. The statistics generally indicate that prior to 1940, total area burned in each state was higher than in more recent years. The same states consistently had the highest number of acres burned. On this basis, it was assumed that the 1925 statistics were representative of the earlier years.

TABLE 10. MISCELLANEOUS INDUSTRIAL PROCESSES

Pulp and paper
Petroleum Refineries
Iron and steel manufacture (sintering, open hearth, roll and finish)
Primary aluminum
Secondary lead (reverberatory and blast furnaces)
Glass manufacturing
Chemicals manufacturing (sulfuric acid, carbon black, petrochemicals, ammonia, nitric acid, TNT)

TABLE 11. MISCELLANEOUS OTHER SOURCES

Aircraft
Vessels (gasoline powered and coal-powered)
Miscellaneous off-highway gasoline
Fuel combustion (LPG, coke-oven gas, bagasse)
Solid waste disposal
Agricultural burning
Coal refuse burning
Prescribed burning

3.14 Miscellaneous

This category consists of two groups, a) miscellaneous industrial processes, and b) miscellaneous other sources not included in the preceding categories. The procedures used to estimate the emissions of both pollutants on the state level for each group are described below.

3.14.1 Miscellaneous Industrial Processes

The industrial processes contained in this category are listed in Table 10. Generally, these processes account for a small percentage of the total emissions of SO_2 and NO_x in each state. They are too large in number to be able to reasonably account for each one separately and are treated as a group for the purposes of this study.

First, total state emissions of this group were obtained from the National Emissions Data System for 1980. Then, the 1980 state emissions were adjusted by a national growth factor. (The factor was obtained by dividing the national emission estimates for each study year by the estimate for 1980. The emissions for study years not reported by the EPA, were estimated by linear interpolation.) For study years prior to 1940, state emissions were estimated by adjusting the state emissions estimated for 1940, by growth factors based on national resident population. This approach is considered reasonable since industrial production is generally proportional to overall population. A more refined approach would require historic production figures for each type of process. However, this information was not available on the state level.

3.14.2 Miscellaneous Other

The individual sources contained in this part are listed in Table 11. The total national emissions of SO_2 and NO_x for each of these sources was obtained from the National Emission Data System for 1980, regarded as the most reliable source for this information.[121] These estimates were then apportioned to the state level by population for the base year 1980. The calculation procedure is outlined below.

1. State population was estimated for each study year from population census data available every tenth year by state and nationally using the following equation:

$$S_{i+j} = (S_{i+10} - S_i) \frac{N_{i+j} - N_i}{N_{i+10} - N_i} + S_i \qquad \text{(eq. 6)}$$

where, S = state population

N = national population

i = census year (1900, 1910, 1920, ... 1970)

j = 5, for the year between two census years, and 8 for 1978

2. Growth factors were derived by dividing the estimated state population for each year by the state population in 1978.
3. Emissions were calculated by multiplying the state growth factor by the 1978 national emissions for this group.

These state estimates were added to the estimates for miscellaneous industrial processes and the totals for each state are shown in Volume II.

4.0 FURTHER IMPROVEMENTS

The historic emission estimates may be improved by improving the fuel consumption, sulfur content and emission factor data bases. Specific improvements that would affect the overall quality of the estimates are described below for each of these variables.

4.1 Fuel Consumption

The fuel consumption data base can be improved by including state consumption data for the years prior to 1950. Presently some fuel consumption data are not available for these years. This improvement requires additional research of historic statistics for certain categories and the use of indirect methods for calculating fuel consumption.

For example, vehicle emissions prior to 1925 could be estimated from the number of registered vehicles or from automobile sales figures. However, such indirect methods are not necessarily as reliable as the present method since these would inherently require additional assumptions. For the years prior to 1960, additional improvement would involve adjusting the reported fuel sales, demand, distribution or shipments to more accurately reflect actual consumption. These adjustments would require techniques similar to those used by the Energy Statistics Branch of the U.S. Department of Energy. This agency has adjusted similar data for the time period between 1960 and 1980.

4.2 Sulfur Content

The SO_2 estimates for the coal and oil-fired source categories can be improved for the years prior to 1950 by using specific sulfur content values instead of assuming a constant 1955 value. This improvement requires further study of historic fuel distribution patterns, fuel properties and consumption during the first half of the century. Based on extensive research during this study, such information is very limited. It is unlikely that further research would provide more definitive data on sulfur content at the state level.

In this study, sulfur content values of heating oils are representative of domestic refined petroleum. However, imported heating oil is a major component of total oil consumption in many states, particularly in the east. Recently, a report by the U.S. Bureau of Mines has been obtained that may provide useful information on the sulfur content of imported oil around 1970.[123] This report gives the quantity of oil by sulfur content ranges and port of entry around 1970, but does not give distribution patterns. The final link to end-use categories and states will require further research and more assumptions, but would provide a more precise estimate of sulfur content than is presently available.

4.3 Emission Factors

The emission estimates can be further improved by using state-specific emission factors instead of national factors. This improvement requires that information on the distribution of various fuels at the state level going to the different source types comprising a source category be located. Average state emission factors can then be calculated from the fuel distribution data and from the emission factors reported for individual sources in AP-42. This improvement would affect the estimates for states where the source distribution significantly deviates from the national distribution. Usually, these are the states with the fewest emission sources.

5.0 QUALITY CONTROL

Control over the quality of the emission estimates was maintained by ensuring that no errors were made during data compilation and that the data bases agreed with other available data. Transcription errors in the fuel consumption data base were located by comparing the total of all state consumption as entered into the data file to the reported national consumption. The continuity of the consumption data and the emission estimates were checked from one study year to the next for each state. Any irregular numbers or discontinuities were checked against the references. Another check involved comparing the total national emissions generated by this study to the historic national totals estimated by the U.S. Environmental Protection Agency.[115] This check helped identify errors in the calculation procedure and in the categorization of emission sources and helped ensure the integrity of the data file.

5.1 Comparison with Other Emission Estimates

The aggregated state emissions derived by this study were compared to the national total emissions reported by the U.S. Environmental Protection Agency (EPA) for 1940, 1950, 1960, 1970 and yearly since 1970.[115] The total state emissions of the electric utility category were compared to the totals estimated by Pechan, et. al. for 1975, 1978 and 1980.[119] The state totals of all categories were compared to the state totals obtained from the NAPAP emission inventory for 1980.[122] These comparisons provide some indication of the precision of the estimates associated with different methods or different approaches. Each comparison is described below.

5.1.1 National Comparison, 1940 to 1980

Table 12 compares the results of this study with the EPA national emission estimates for major source categories. The estimates are similar, but are not identical due to differences inherent in methodologies and differences created by the additional assumptions required for state-level estimates, as described in this report. Other differences stem from numerical round-off and differences in calculation procedures. For example, the EPA national estimates were obtained by applying an emission factor to the sum of state-level fuel consumption as is illustrated by the following equation.

$$\text{National Emissions}_j = (a + b + c + \ldots.) \times EF_j \qquad \text{(eq. 7)}$$

where, a, b, c ... = fuel consumption by each state by a source category

EF = emission factor

j = source category

TABLE 12. COMPARISON BETWEEN AGGREGATED STATE TOTALS AND EPA NATIONAL ESTIMATES

NOTE: Numbers in brackets are EPA National Totals[a]

SULFUR OXIDE EMISSIONS (1,000 TONS).

YEAR

Major Source Category	1940	1950	1960	1970	1975	1978	1980
Electric Utilities	2,384. (2,425.)	4,526. (4,519.)	9,250. (9,259.)	17,692. (17,417.)	19,489. (18,298.)	17,261. (17,417.)	17,986. (17,086.)
Industrial	6,690. (6,063.)	3,811. (5,732.)	3,569. (3,858.)	3,348. (4,520.)	1,995. (2,976.)	2,465. (2,976.)	1,314. (2,646.)
Commerical Residential	3,241. (3,638.)	2,873. (3,968.)	2,096. (2,315.)	1,933. (1,543.)	1,343. (1,103.)	1,239. (1,213.)	926. (992.)
Highway Vehicles	53. b	101. (110.)	144. (110.)	298. (331.)	366. (331.)	456. (441.)	480. (441.)
All Others	7,566. (7,826.)	9,882. (8,158.)	7,210. (6,614.)	8,679. (7,495.)	6,575. (5,621.)	6,060. (5,070.)	6,491. (4,519.)
Total	20,519. (19,952.)	21,203. (22,487.)	22,269. (22,156.)	31,946. (31,306.)	29,520. (28,329.)	27,249. (27,117.)	27,197. (25,684.)
Percent Difference[e]	-2.8%	+5.7%	-0.5%	-2.0%	-4.2%	-0.5%	-5.8%

NITROGEN OXIDE EMISSIONS (1,000 tons)
YEAR

Major Source Category	1940	1950	1960	1970	1975	1978	1980
Electric Utilities	646. (661.)	1,312. (1,323.)	2,580. (2,535.)	5,109. (4,960.)	6,257. (5,732.)	6,742. (6,504.)	7,924. (7,055.)
Industrial plus pipelines	2,210. (2,425.)	2,823. (3,197.)	4,227. (4,079.)	4,265. (4,299.)	3,724. (3,748.)	4,152. (4,079.)	3,494. (3,307.)
Commercial-Residential	259.[c] (551.)	613.[c] (661.)	688.[c] (772.)	831. (772.)	748. (772.)	769. (772.)	713. (772.)
Highway Vehicles	1,345. (1,433.)	2,286. (2,205.)	3,469. (3,858.)	6,206. (6,614.)	7,353. (7,937.)	8,055. (8,598.)	7,656. (8,377.)
All Others	3,098.[d] (2,315.)	3,275. (2,755.)	2,646. (2,755.)	2,803. (3,307.)	2,389. (2,975.)	2,697. (3,416.)	2,471. (3,307.)
Total	7,558. (7,385.)	10,309. (10,141.)	13,610. (13,999.)	19,402. (19,952.)	20,501. (21,164.)	22,414. (23,369.)	22,259. (22,818.)
Percent Difference[e]	-2.3%	-1.6%	+2.8%	+2.8%	+3.1%	+4.1%	+2.4%

[a] The EPA national totals include Alaska and Hawaii. The estimates are reported in Reference 115 and are reported in units of teragrams/year significant to 0.1 teragrams/year. These units were converted to units of 1,000 tons by multiplying by 1.1023×10^3, but are significant only to 100,000 tons.

[b] Reported as 0.0 teragrams. This converts to less than 55,000 tons.

[c] Significant differences occur because in this study, emission factors varied as a function of time to reflect the predominance of residential sources in the earlier part of the century while EPA estimates are based on the same average factor for all year.

[d] Includes 80,000 tons from wood-all uses category. For subsequent years, this category is subdivided and emissions are included under the first three major categories listed.

[e] Calculated as follows: $\frac{\text{EPA National Total - Study Total}}{\text{Study Total}} \times 100$

In this study the total national emissions were derived by aggregating individual state emissions as is illustrated below:

$$\text{National Emissions}_j = (a \times EF_j) + (b \times EF_j) + (c \times EF_j) + \ldots \quad \text{(eq. 8)}$$

These two methods can yield slightly different values due to numerical round-off. Theoretically, the methods can result in as much as a 2.5 percent difference in the national estimates from round-off alone when the state-level emissions calculated in equation 8 are rounded to the nearest 1,000 tons. The total SO_2 emissions estimated by this study are within 5.8 percent of the EPA estimates for all years compared and the total NO_x emission estimates are within 4.1 percent.

5.1.2 Comparison of Electric Utilities, 1975 to 1980

Table 13 compares the state SO_2 emission estimates of this study with those of Pechan, et. al. for coal-fired electric utilities for comparable years. The principal difference between the two sets of estimates lies in the level of detail. Pechan, et. al. estimated the SO_2 emissions after controls on a plant-by-plant basis and aggregated the plant emissions to the state level. Their estimates were based on the average quality of all types of coal combined at the power plant level. In this study the same basic data on fuel consumption and fuel quality were used, but the estimates were based on the average quality of bituminous coal. This approach was necessary because on a historic basis individual plant data on fuel quality are generally not available. Differences in the sulfur content values used by each study may also account for some difference, but is estimated to be less than about 2.0 percent on the state level. Additional differences may occur due to different numerical round-off and calculation procedures. On the state level, the estimates are close, but on a percentage basis they are higher for states with the lowest emissions or fewer power plants. For all states combined, the SO_2 emissions estimated by this study are within 8.4 percent of the estimates by Pechan, et. al. for coal-fired electric utilities.

Table 14 compares the SO_2 emissions for oil-fired electric power plants. Pechan also estimated these on a plant-by-plant basis after controls, but applied one emission factor to the total amount of oil burned. In this study, emissions were calculated separately for residual

TABLE 13. COMPARISON BETWEEN COAL-FIRED ELECTRIC UTILITY SO_2 EMISSIONS OF THIS STUDY AND THOSE OF PECHAN, *et. al.*

SO_2 Emissions (1000 tons)
YEAR

State	1975		1978		1980	
	This Study	Pechan	This Study	Pechan	This Study	Pechan
Alabama	884.6	734.9	491.2	528.1	560.2	542.4
Arizona	31.6	35.3	55.4	47.3	81.0	82.8
Arkansas	0.0	0.0	13.2	5.9	25.1	10.6
California	0.0	0.0	0.0	0.0	0.0	0.0
Colorado	51.8	56.0	79.2	74.8	92.9	76.2
Connecticut	0.0	0.2	0.1	0.6	0.0	0.0
Delaware	13.3	43.5	15.3	30.4	34.0	31.9
District of Columbia	3.3	1.5	0.0	0.0	0.0	0.0
Florida	199.4	299.2	192.8	268.9	296.7	361.9
Georgia	537.6	439.7	556.6	580.1	704.5	730.4
Idaho	0.0	0.0	0.0	0.0	0.0	0.0
Illinois	1,752.8	1,403.2	1,275.2	1,262.6	1,161.8	1,093.8
Indiana	1,598.1	1,462.5	1,321.3	1,346.1	1,643.4	1,537.2
Iowa	212.8	185.5	288.1	262.6	231.6	230.7
Kansas	122.0	83.4	155.3	143.6	221.7	147.6
Kentucky	1,276.7	1,360.4	1,243.4	1,209.8	1,052.1	1,006.8
Louisiana	0.0	0.0	0.3	0.0	24.2	0.0
Maine	0.0	0.0	0.0	0.0	0.0	0.0
Maryland	130.0	120.7	132.9	137.8	211.9	184.6
Massachusetts	4.8	12.2	0.0	0.0	7.1	14.9
Michigan	1,030.5	973.7	762.9	759.4	583.2	540.9
Minnesota	192.2	199.1	135.4	181.3	121.2	174.8
Mississippi	50.8	71.7	73.1	67.0	101.3	84.6
Missouri	1,066.9	1,073.6	1,040.2	1,009.0	1,099.4	1,138.6
Montana	14.9	13.2	22.1	21.8	30.7	23.2
Nebraska	25.6	21.9	44.2	34.0	49.7	48.5
Nevada	30.5	29.7	31.0	32.1	39.1	33.4
New Hampshire	48.1	45.3	33.3	32.3	46.4	52.3
New Jersey	86.0	78.4	62.6	70.7	88.0	78.6
New Mexico	82.8	73.7	99.3	80.7	112.2	83.7
New York	249.8	225.4	211.3	204.8	210.9	225.8
North Carolina	437.2	373.4	415.6	391.0	429.7	433.5
North Dakota	46.9	41.5	70.9	71.6	93.2	82.3
Ohio	2,649.9	2,703.0	2,253.9	2,449.9	2,344.6	2,163.2
Oklahoma	0.0	0.0	10.1	12.7	59.3	37.4
Oregon	0.0	0.0	0.5	0.0	11.9	2.9
Pennsylvania	1,418.8	1,418.6	1,089.5	1,267.5	1,377.6	1,417.0
Rhode Island	0.0	0.0	0.0	0.0	0.0	0.0
South Carolina	114.6	108.9	156.8	155.8	190.2	196.6
South Dakota	32.0	20.9	46.4	31.8	38.2	28.4
Tennessee	1,349.3	1,027.2	891.8	1,021.0	1,002.6	932.3
Texas	75.2	81.4	174.2	167.6	294.3	297.2
Utah	19.5	19.6	25.4	29.8	27.6	21.8
Vermont	0.3	0.3	0.0	0.2	0.0	0.3
Virginia	64.8	62.7	88.6	79.6	94.9	95.7
Washington	37.0	34.8	89.9	69.8	81.2	68.2
West Virginia	1,299.8	1,029.5	1,091.2	894.0	1,059.1	942.0
Wisconsin	552.5	464.8	588.0	468.4	522.9	483.6
Wyoming	76.3	58.9	113.5	95.6	167.6	120.4
Total	17,871.0	16,489.4	15,441.1	15,597.7	16,625.2	15,859.1
Percent Difference[a]	-8.4%		+1.0%		-4.8%	

[a] Calculated as follows: $\frac{\text{Pechan's Total - Study Total}}{\text{Study Total}} \times 100$

TABLE 14. COMPARISON BETWEEN OIL-FIRED ELECTRIC UTILITY SO_2 EMISSIONS OF THIS STUDY AND THOSE OF PECHAN, et. al.

SO_2 Emissions (1000 tons)
YEAR

State	1975		1978		1980	
	This Study	Pechan	This Study	Pechan	This Study	Pechan
Alabama	0.3	1.0	0.5	2.5	0.1	0.7
Arizona	16.5	17.1	8.7	12.2	3.7	4.7
Arkansas	16.0	16.7	50.8	53.1	13.1	16.0
California	113.9	123.2	80.1	107.5	84.8	77.7
Colorado	4.3	3.2	1.3	1.8	0.4	1.3
Connecticut	32.0	32.1	25.8	25.5	29.4	32.1
Delaware	20.9	18.5	21.0	25.2	20.5	20.6
District of Columbia	6.5	5.5	4.7	10.4	1.9	4.6
Florida	375.0	357.2	321.3	326.2	353.7	364.0
Georgia	26.4	24.4	33.8	36.1	1.2	6.3
Idaho	0.0	0.0	0.0	0.0	0.0	0.0
Illinois	26.5	20.4	30.8	30.2	29.2	31.8
Indiana	2.1	1.3	4.4	5.1	0.9	2.4
Iowa	0.6	0.8	1.1	1.1	0.0	0.6
Kansas	15.3	17.2	14.1	15.7	0.1	2.5
Kentucky	0.1	0.1	0.2	0.2	0.2	0.8
Louisiana	12.6	11.8	59.2	63.7	15.5	24.7
Maine	20.4	20.1	8.9	8.7	14.3	16.3
Maryland	75.5	70.1	81.4	82.7	33.7	38.6
Massachusetts	98.8	97.4	257.1	258.9	262.0	260.6
Michigan	40.1	37.9	47.3	47.5	20.6	24.4
Minnesota	9.5	6.5	7.7	8.9	1.4	2.5
Mississippi	63.9	60.9	141.2	141.7	36.4	44.5
Missouri	5.1	2.0	5.4	4.6	0.6	2.0
Montana	0.1	0.0	0.1	0.0	0.1	0.2
Nebraska	2.5	1.8	4.2	3.9	0.2	1.0
Nevada	3.5	3.0	6.1	6.5	6.1	6.1
New Hampshire	14.9	14.0	17.8	20.0	26.5	28.1
New Jersey	32.0	29.1	39.9	44.6	19.2	31.7
New Mexico	2.5	2.5	0.2	0.7	0.4	0.9
New York	333.4	312.6	284.3	315.2	255.5	290.7
North Carolina	0.4	0.5	4.3	5.4	0.3	0.3
North Dakota	0.0	0.0	0.1	0.1	0.1	0.2
Ohio	11.9	7.3	12.0	12.6	1.6	8.3
Oklahoma	2.5	0.2	0.3	0.2	0.0	0.2
Oregon	1.2	0.0	0.0	0.1	0.3	0.4
Pennsylvania	21.4	17.3	55.0	55.2	38.1	49.1
Rhode Island	5.2	4.1	3.8	3.4	4.2	5.2
South Carolina	28.8	30.7	34.9	37.0	12.6	16.5
South Dakota	0.5	0.4	0.3	0.6	0.1	0.2
Tennessee	1.7	3.0	4.6	12.1	0.4	1.4
Texas	9.5	3.0	8.0	11.7	2.9	5.2
Utah	0.1	0.2	0.2	0.2	0.1	0.3
Vermont	0.1	0.0	0.0	0.1	0.0	0.2
Virginia	157.9	146.4	134.5	144.3	64.4	67.9
Washington	0.0	0.0	0.0	0.0	1.3	1.2
West Virginia	0.6	0.3	1.4	1.5	0.6	2.3
Wisconsin	3.4	3.0	1.9	3.2	0.5	2.1
Wyoming	0.1	0.1	0.1	0.2	0.1	0.4
Total	1,616.5	1,525.9	1,820.8	1,948.3	1,359.3	1,465.0
Percent Difference[a]	-5.9%		+6.5%		+7.2%	

[a] Calculated as follows: $\frac{\text{Pechan's Total - Study Total}}{\text{Study Total}} \times 100$

TABLE 15. COMPARISON OF TOTAL STATE SO_2 AND NO_x EMISSIONS OF THIS STUDY AND THE NAPAP EMISSION INVENTORY FOR 1980

Emissions (1000 tons)

State	SO_2		NO_x	
	This Study	NAPAP	This Study	NAPAP
Alabama	788.	850.	509.	525.
Arizona	793.	844.	326.	294.
Arkansas	88.	89.	222.	232.
California	574.	533.	1,404.	1,323.[a]
Colorado	150.	134.	310.	292.
Connecticut	62.	69.	142.	143.
Delaware	101.	127.	60.	69.
District of Columbia	6.	17.	22.	27.
Florida	997.	1,202.	702.	629.
Georgia	818.	877.	560.	587.
Idaho	28.	55.	111.	90.
Illinois	1,579.	1,459.	1,017.	1,118.[b]
Indiana	2,076.	1,880.	857.	860.
Iowa	338.	390.	312.	349.
Kansas	281.	231.	449.	592.[c]
Kentucky	1,184.	1,158.	566.	604.
Louisiana	415.	501.	880.	821.
Maine	66.	133.	62.	64.
Maryland	359.	296.	284.	278.
Massachusetts	346.	362.	267.	272.
Michigan	905.	878.	727.	746.
Minnesota	187.	263.	309.	456.[d]
Mississippi	264.	306.	276.	295.
Missouri	1,283.	1,297.	541.	607.
Montana	163.	168.	130.	129.
Nebraska	72.	77.	172.	210.
Nevada	220.	146.	110.	123.
New Hampshire	87.	107.	55.	60.
New Jersey	329.	303.	411.	434.
New Mexico	284.	258.	327.	307.
New York	934.	864.	709.	748.
North Carolina	583.	653.	560.	570.
North Dakota	121.	114.	141.	168.[d]
Ohio	2,814.	2,705.	1,181.	1,219.
Oklahoma	147.	102.	486.	462.
Oregon	61.	55.	202.	227.
Pennsylvania	2,011.	1,851.	1,172.	1,082.
Rhode Island	13.	14.	36.	36.
South Carolina	304.	342.	271.	302.
South Dakota	47.	41.	78.	77.
Tennessee	1,177.	1,134.	581.	573.
Texas	1,312.	1,341.	2,549.	3,486.[c,d]
Utah	114.	116.	175.	175.
Vermont	7.	10.	25.	44.
Virginia	313.	385.	411.	411.
Washington	280.	325.	298.	350.
West Virginia	1,205.	1,104.	500.	473.
Wisconsin	677.	688.	438.	426.
Wyoming	243.	249.	327.	299.
Total	27,196.	27,111.	22,260.	23,667.
Percent Difference[e]	-0.3%		+5.9%	

[a] The difference in total NO_x emissions stems mostly from the transportation categories.

[b] The higher value reported by NAPAP is due to a preponderance of power plants with higher emission factors.

[c] Data in the NAPAP emission inventory that was obtained from NEDS are not consistent with the national average emission factor used in this study.

[d] The difference in total NO_x emissions stems mostly from the electric utilities category. This study assumed that all coal consumed by this category in Minnesota, North Dakota, and Texas, while in reality it is a mixture.

[e] Calculated as follows: $\frac{\text{NAPAP Total - Study Total}}{\text{Study Total}} \times 100$

and distillate oil. On the state level, the estimates of both studies are in general agreement and overall are within 7.2 percent for all three years that were compared.

5.1.3 Comparison with the 1980 NAPAP Emission Inventory

Table 15 compares the state total emissions estimated by this study for 1980 with the results of the NAPAP emission inventory. It should be noted that the methodologies to derive each data base are not comparable. NAPAP is based on a "bottom-up" approach where point and area sources are inventoried on an individual source basis, while this study was based on a "top-down" approach where generalizations are made regarding broad categories of sources. The NAPAP data base for 1980 represents the most detailed account of sources and emissions available to date. It is expected to undergo further refinement and improvements in the future. Considering the fundamental differences in methodology, it is interesting to note the general similarity in the total state emissions. For all states combined, the percentage difference was 0.3 percent for SO_2 and 5.9 percent for NO_x. Major differences in total state NO_x emissions are explained in footnotes to Table 15.

5.2 Probable Error of Estimates

These comparisons give an indication of the precision of the estimates derived by independent studies using various methodologies, calculation procedures and assumptions. The comparisons do not give an indication of accuracy because this would require knowing the actual emissions. This is impossible to determine on the state and national levels or even at a smaller scale and, therefore, estimating procedures are required.

The comparisons indicate that the results of this study are similar to those of more detailed studies for the recent years. The uncertainty of the estimates may be determined by computing the probable error of the estimates. Such an analysis is planned for the NAPAP inventory and the results may provide a basis for estimating the uncertainty of the historic emission estimates for 1980. Once the uncertainty of the 1980 estimates is known, the uncertainty for earlier years can be estimated by assigning uncertainty bounds to each assumption introduced over time.

6.0 AVAILABILITY OF DATA ON COMPUTER TAPE

All emission estimates resulting from this study are available on computer tape. These estimates are presented on tape in the same format as they are presented in Volume II. The data tape contains the annual fuel consumption of each state presented by source category and study year. It also contains the average sulfur content values and emission factors used and also shown in Volume II. In addition, the tape contains all SO_2 and NO_x emission estimates for each state by source category and by study year. It also contains special data files such as the smelter emissions, wildfires and miscellaneous category from 1900 to 1980 which were calculated separately.

CHAPTER III

METHOD OF ESTIMATING YEARLY EMISSIONS

1.0 POSSIBLE APPROACHES

Emission estimates for every fifth year may be adequate for most studies requiring only a general indication of emission trends. However, for studies of material damage and aquatic and biological effects, yearly estimates may be needed. To provide yearly estimates of total state emissions one of two approaches may be used. Each has advantages and limitations.

One approach involves proportioning the emissions derived in this study for every fifth year by major fuel type to the intervening years on the basis of the change in the national consumption of the fuel. For example, if the national fuel consumption of coal increased, then the state level emissions attributed to coal will increase by a proportionate amount. A more refined version of this approach involves proportioning on the basis of fuel consumed by each individual source category. However, historic fuel consumption data are not available for all source categories so this approach would provide incomplete results.

The other approach involves applying the methodology as described in Chapter II to the intervening years. This approach would produce the best results because it incorporates actual fuel consumption and sulfur content on the state level to the greatest extent possible. However, this approach is more complicated and would best be used only after improvements have been made to the existing methodology regarding emission factors and sulfur content values as described in the previous chapter. This approach would be most appropriate for the time period 1960 to 1980, for which annual fuel consumption data are available for most source categories on the state level from State Energy Data Reports.[59] For years prior to 1950, this approach may be limited to the availability of information on certain source categories.

In order to provide yearly emission estimates on the state level in this study, the first approach was selected. It provided a reasonable alternative pending further improvements to the present version of the emissions data base.

2.0 INTERPOLATION PROCEDURE

The basic interpolation procedure is based on the following assumed proportion.

$$\frac{SE_{i+k+1} - SE_{i+k}}{SE_{i+5} - SE_{i+k}} = \frac{NE_{i+k+1} - NE_{i+k}}{NE_{i+5} - NE_{i+k}} \qquad \text{(eq. 9)}$$

where, SE = state emissions of each fuel type category
NE = national energy consumption
i = study year (i.e., 1900, 1905, . . ., 1975)
k = integer (0, 1, 2, or 3) to represent each intervening year.

Solving this relationship for SE_{i+k+1}, yields the following equation.

$$SE_{i+k+1} = (SE_{i+5} - SE_{i+k}) \; \frac{NE_{i+k+1} - NE_{i+k}}{NE_{i+5} - NE_{i+k}} + SE_{i+k} \qquad \text{(eq. 10)}$$

This equation is based on the ratio of changes in the national fuel consumption to changes in the state level emissions by fuel type category on a year-by-year basis. For example, state emissions for 1942 (i = 1940, k = 1) are calculated using the national and state data for 1945 and 1941 and the national data for 1942. The calculation procedure begins with 1901 and the results for 1901 are then used for estimating 1902 and so on. For each year, the equation was applied to each major fuel type category; bituminous coal, anthracite, distillate and residual oil (combined), natural gas, wood, and gasoline and diesel fuel combined. The state emission values (SE) for each category were obtained from Volume II, Section 4.0. The national energy consumption (NE) by fuel type was obtained for each year from 1900 to 1980 from various references. The fuel data and the references are presented in Appendix A.

The equation produces reasonable results except in a few cases when the national fuel consumption either increased or decreased by a large amount from one year to the next, or over the time period reflected in the denominator of the equation. These special situations, which result in anomalies, occur in 1912 and 1913 when the national consumption of bituminous coal increased and in 1971 when it decreased sharply, and in 1931, 1932, and 1933 when the consumption of natural gas decreased. In these cases, the emissions of the affected category were estimated using the method of linear interpolation described below.

Annual emissions of the categories not included in the above procedure, were estimated using linear interpolation. These categories included smelters, cement plants, wildfires, miscellaneous industrial processes and miscellaneous other. The emissions of these categories were added for each state and the following equation was applied to their sum:

$$SE_{i+j} = SE_i + (SE_{i+5} - SE_i) \times j \div 5 \qquad \text{(eq. 10)}$$

where, SE = total state emissions of these other categories
i = study year
j = integer (1, 2, 3 or 4) to represent each intervening year.

The interpolated emission estimates for each major category were then added to yield total state emission estimates for each consecutive year.

3.0 TOTAL ANNUAL STATE EMISSION ESTIMATES

The total state emissions for each study year and the intervening years are plotted in Figure 9 and are presented in numerical form for each state in Appendix A. It should be remembered that the emissions for each study year were derived by aggregating estimates for individual source categories. The emissions for the intervening years were interpolated using the procedure described in the previous section. The resulting numbers which are also displayed in Appendix A are available on computer tape.

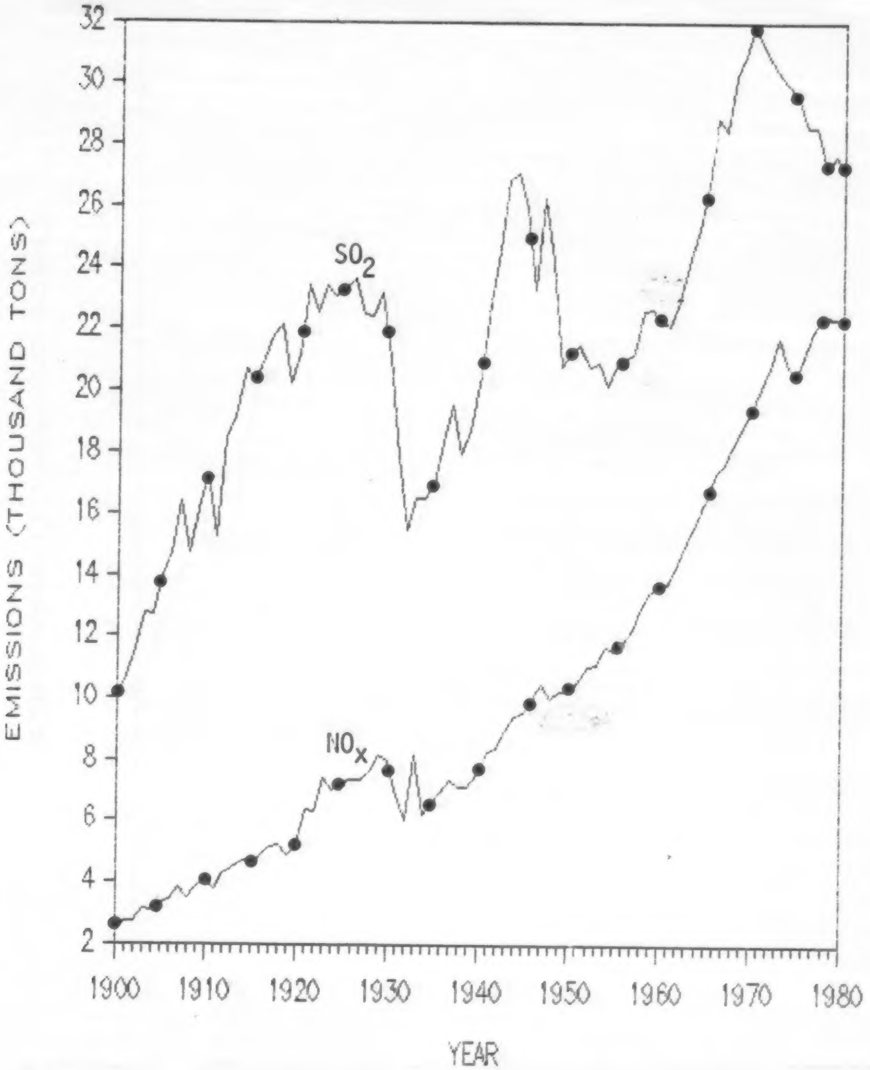

Figure 9. Annual SO_2 and NO_x emissions of the conterminous United States: 1900 to 1980. (Dots represent the result of the methodology described in Chapter II for every fifth year and 1978. For the other years, the interpolation procedure is described in Chapter III.)

REFERENCES FOR CHAPTERS II and III

33. U.S. Department of the Interior, Bureau of Census. Minerals Yearbook, 1955. Washington, D.C., Government Printing Office.

34. Reference 33, 1951.

35. Reference 33, 1970.

36. Reference 33, 1975.

37. Reference 33, 1950.

38. U.S. Department of the Interior, Bureau of Census. Mineral Industry Survey, Natural Gas Production and Consumption. Washington D.C., Government Printing Office, 1970 and 1975.

39. Reference 38, Sales of Fuel Oil and Kerosene.

40. U.S. Department of the Interior, Bureau of Mines. Supply and Demand for Energy in the United States by States and Regions, 1960 and 1965, Information Circular 8401.

41. Reference 40, Petroleum and Natural Gas Liquids.

42. Reference 40, Coal.

43. U.S. Department of Energy. Energy Data Report, Bituminous and Subbituminous Coal and Lignite Distribution-Calendar year 1978. DOE/EIA-0125(4Q78), Washington, D.C., April 1979.

44. U.S. Department of Energy. Energy Data Report, Sale of Fuel Oil and Kerosene in 1978. DOE/EIA-0113(8), Washington, D.C., November 1979.

45. U.S. Department of Energy. Energy Data Report, Natural Gas Production and Consumption in 1978. DOE/EIA-0131(78), Washington, D.C., October 1979.

46. National Coal Association. Steam Electric Plant Fuel Consumption and Costs. Washington, D.C., 1950.

47. U.S. Department of the Interior, Bureau of Census. U.S. Census of Mineral Industries: 1954 Vol. I, Summary and Industry Statistics. Washington, D.C., Government Printing Office, 1958.

48. American Petroleum Institute. Petroleum Facts and Figures, U.S. Sales of Distillate Oils by State, 1937 to 1969. Washington, D.C.

49. Reference 48, U.S. Sales of Residual Oils by State, 1937 to 1969.

50. U.S. Department of Transportation, Federal Highway Administration. Highway Statistics. Washington, D.C., 1970.

51. Reference 50, 1976.

52. Reference 50, 1978.

53. Reference 50, 1980.

54. U.S. Department of Transportation, Federal Highway Administration. Highway Statistics Summary to 1965. Washington, D.C., March 1967.

55. Reference 46, 1955.

56. U.S. Department of Energy. Energy Data Report, Deliveries of Fuel Oil and Kerosene in 1980. DOE/EIA-0113(80), Washington, D.C., February 1982.

57. U.S. Department of Energy. Natural Gas Annual 1980. DOE/EIA-0131(80), Washington, D.C., March 1980.

58. U.S. Department of Energy. Energy Data Report, Coal Distribution January-December 1980. DOE/EIA-0125(80/4Q), Washington, D.C., April 1981.

59. U.S. Department of Energy. State Energy Data Report - 1960 through 1980. DOE/EIA-0214(80), Washington, D.C., July 1982.

60. U.S. Department of Energy. Energy Data Report, Coal-Pennsylvania Anthracite 1978. DOE/EIA-0119(78), Washington, D.C., October 1980.

61. Reference 33, Coke and Coal Chemicals, 1950.

62. Reference 33, Coke and Coal Chemicals, 1955.

63. Reference 33, Consumption of Bituminous Coal and Lignite by Consumer Class, with Retail Deliveries in the United States 1933-60. p. 454, 1960.

64. U.S. Department of Energy. Estimates of U.S. Wood Energy Consumption from 1949 to 1981. DOE/EIA-0341, Washington, D.C., August 1982.

65. U.S. Environmental Protection Agency. Internal Memorandum from Roy A. Rathburn to John Pratapus, December 21, 1981, Data provided by Regions in response to requests for information from Senator Stafford and Congressman Waxman.

66. Reference 33, Cement-Portland Cement Production Capacity and Stocks in the U.S. by District, Annual 1950-1980.

67. 1976 Keystone Coal Industry Manual. Charles H. Daly (Publisher). McGraw Hill Mining Publications, New York, NY.

68. Reference 33, 1965.

69. Data provided by Dr. Rudolf B. Husar, Center for Air Pollution Impact and Trends Analysis, Washington University, St. Louis, MO.

70. U.S. Bureau of Mines. Mineral Resources of the United States 1915, Anthracite. Washington, D.C.

71. Reference 70, 1941.

72. Reference 70, 1945.

73. U.S. Bureau of Mines. Mineral Resources of the United States 1930. Domestic-Industrial Consumption of Natural Gas. p. 466-475.

74. Reference 73, 1941, p. 1143-1144.

75. Reference 73, 1946. p. 832.

76. U.S. Bureau of Mines. Mineral Resources of the United States 1910. Part II-Nonmetals, Distribution of Natural Gas. p. 304.

77. Reference 76, 1915, p. 936.

78. Reference 76, 1921, p. 353-355.

79. Reference 76, 1925, p. 132.

80. Reference 76, 1930, p. 472.

81. Reference 76, 1941, p. 1141.

82. Reference 76, 1946, p. 831.

83. U.S. Bureau of Mines. Mineral Resources of the United States 1900. Part II - Nonmetals, Portland Cement produced and shipped in the United States. p. 737.

84. Reference 83, 1905, p. 926.

85. Reference 83, 1910, p. 471.

86. Reference 83, 1915, p. 195.

87. Reference 83, 1920, p. 267.

88. Reference 83, 1925, p. 258.

89. Reference 83, 1930, p. 407.

90. Reference 83, 1935, p. 791.

91. Reference 83, 1940, p. 1141.

92. Reference 83, 1945, p. 831.

93. U.S. Department of Energy. Energy Data Reports, Cost & Quality of Fuels for Electric Utility Plants 1980 Annual. DOE/EIA-0191 (80), Washington, D.C., p. 87-92.

94. Federal Power Commission. Fuel Use Reports-Form 67, obtained from U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, National Air Data Branch, Research Triangle Park, NC.

95. U.S. Department of the Interior, Bureau of Mines. Sulfur Content of United States Coals. Information Circular 8312.

96. U.S. Department of the Interior, Bureau of Mines. Burner Fuel Oils, 1970. Petroleum Products Survey No. 67, November 1970.

97. U.S. Energy Research & Development Administration. Heating Oils, 1975. BERC/PPS-75/2 by Ella Mae Shelton, Bartlesville Energy Research Center, Bartlesville, OK, August 1975.

98. U.S. Department of Energy. Sulfur Content in Coal Shipments 1978. DOE/EIA-0263(78), Washington, D.C., June 1981.

99. U.S. Department of the Interior, Bureau of Mines. Mineral Industry Survey. Bituminous Coal and Lignite Distribution-Calendar Year 1975, Washington, D.C., April 12, 1976.

100. U.S. Department of the Interior, Bureau of Mines. Mineral Industry Surveys. Bituminous Coal and Lignite Distribution-Calendar Year 1970, Washington, D.C., March 23, 1971.

101. U.S Department of the Interior, Bureau of Census. Minerals Yearbook, 1970. Shipments of Bituminous Coal and Lignite and Average Sulfur Content by Consumer Use in 1970. Washington, D.C.

102. U.S. Department of Interior, Bureau of Mines. National Survey of Burner Fuel Oils, 1955 by O.C. Blade. Information Circular 7730, October, 1955.

103. U.S. Department of Interior, Bureau of Mines. Burner Fuel Oils, 1960 by O.C. Blade. Petroleum Products Survey No. 16, October 1960.

104. U.S. Department of Interior, Bureau of Mines. Burner Fuel Oils, 1965 by O.C. Blade. Petroleum Products Survey No. 41, September 1965.

105. U.S. Department of Energy, Technical Information Center. Heating Oils, 1978 by Ella Mae Shelton, Bartlesville Energy Technology Center, Bartlesville, OK. DOE/BETC/PPS-78/4, August 1978.

106. U.S. Department of Energy, Technical Information Center. Heating Oils, 1980 by Ella Mae Shelton, Bartlesville Energy Technology Center, Bartlesville, OK. DOE/BETC/PPS-80/4, October, 1980.

107. 1955 Keystone Coal Buyers Manual. Carl J. Coash (Publisher). McGraw-Hill Publishing Co. Inc. New York, NY, pg. 277-372 and 431-682.

108. U.S. Department of the Interior, Bureau of Mines. Mineral Industry Survey. Bituminous Coal and Lignite Distribution-Calendar Year 1957. Washington, D.C., August 1958.

109. S.H. Schurr, B.C. Netschert, V.F. Eliasberg, J. Lerner, and H.H. Landsberg. Energy in the American Economy, 1850-1975. Published for Resources for the Future, Inc., by the Johns Hopkins Press, Baltimore, MD.

110. U.S. Environmental Protection Agency. EPA Utility FGD Survey, October-December 1981. EPA-600/7-82-058 (NTIS PB83-168054), Research Triangle Park, NC. September 1982.

111. U.S. Environmental Protection Agency. Compilation of Air Pollutant Emission Factors. AP-42, Third Edition (NTIS PB-275525), Supplements 1-7 and 8-14, Research Triangle Park, NC.

112. U.S. Environmental Protection Agency. Mobile Source Emission Factors. EPA-400/9-78-005 (NTIS PB295672/A17), Washington, D.C., March 1978.

113. United States-Canada Memorandum of Intent 1982. Emissions, Costs and Engineering Assessment - Final Report of Work Group 3B. Available from the U.S. Environmental Protection Agency, Washington, D.C., June 15, 1982.

114. U.S. Environmental Protection Agency. Estimates of Sulfur Oxide Emissions from the Electric Utility Industry: Volumes I and II. EPA-600/07-82-061 (NTIS PB83-130229), Washington, D.C., March 1983.

115. U.S. Environmental Protection Agency. National Air Pollutant Emission Estimates, 1940-1982. EPA-450/4-83-024 (NTIS PB84-121391/MF), Research Triangle Park, NC, February 1984.

116. U.S. Environmental Protection Agency. Analysis of State and Federal Sulfur Dioxide Emisson Regulations for Combustion Sources. EPA-450/2-81-079 (NTIS PB83-179838/A07), Research Triangle Park, NC, November 1981.

117. U.S. Department of Agriculture, Forest Service. Wildfire Statistics. Washington, D.C., Annual from 1911.

118. U.S. Environmental Protection Agency. Background Information for New Source Performance Standards: Primary Copper, Zinc and Lead Smelters Volume 1: Proposed Standards. EPA-450/2-74-002a (NTIS PB237832), Research Triangle Park, NC, October 1974.

119. E.H. Pechan, J.H. Wilson, Jr. Estimates of 1973-1982 Annual Sulfur Oxide Emissions from Electric Utilities. J. of Air Pol. Control Assoc., 34 (10): pp. 1075-1078, 1984.

120. U.S. Environmental Protection Agency. Status Report on the Development of the NAPAP Emission Inventory for the 1980 Base Year and Summary of Preliminary Data. EPA-600/7-84-091, Research Triangle Park, NC, December 1984.

121. National Emissions Report, National Emissions Data System (NEDS). EPA-450/4-83-022 (NTIS PB84-121375/MF), U.S. Environmental Protection Agency, Research Triangle Park, NC, 1984.

122. M. Marians, J. Trijonis. Empirical Studies of the Relationship Between Emissions and Visibility in the Southwest. EPA-450/5-79-009 (NTIS PB80-156136/A06), U.S. Environmental Protection Agency, Research Triangle Park, NC, 1979.

123. Import Supplement to Oil Availability by Sulfur Levels. By Staff, U.S. Bureau of Mines for Environmental Protection Agency, Office of Air Programs, June 1972.

APPENDIX A

INTERPOLATED TOTAL EMISSIONS

LIST OF TABLES

Table | | Page
A-1 Total National Fuel Consumption by Major Source: 1900 to 1980 70

A-2 Summary of Total SO_2 Emissions by State 72

A-3 Summary of Total NO_x Emissions by State 86

TABLE A-1. TOTAL NATIONAL FUEL CONSUMPTION BY MAJOR SOURCE: 1900 TO 1980

(Trillion Btu's)

YEAR	BITUMINOUS COAL[a]	ANTHRACITE COAL[a]	CRUDE PETROLEUM[a]	PETROLEUM PRODUCTS[a,b]	NATURAL GAS	FUEL WOOD[c]	GASOLINE, DIESEL[d]
1900	5431	1410	229	0	252	2480	0
1901	5808	1657	250	0	281	2438	1
1902	6733	1030	364	0	299	2395	1
1903	7315	1843	449	0	317	2353	2
1904	7155	1797	534	0	330	2311	3
1905	8091	1910	610	0	372	2268	4
1906	8793	1748	555	0	411	2249	5
1907	10079	2098	781	0	432	2230	7
1908	8478	2037	820	0	427	2211	10
1909	9685	1978	844	0	511	2192	16
1910	10654	2060	1007	0	540	2172	24
1911	10245	2197	1040	0	544	2153	32
1912	11402	2038	1058	0	594	2135	45
1913	12034	2207	1210	0	620	2116	62
1914	10703	2198	1320	0	632	2097	86
1915	11134	2160	1411	0	673	2078	120
1916	12631	2106	1497	0	807	2058	172
1917	13835	2378	1755	0	850	2039	244
1918	14588	2385	1911	0	771	2020	285
1919	11688	2113	2159	0	793	2001	344
1920	13325	2179	3027	-393	827	1982	430
1921	10266	2082	3016	-342	682	1963	506
1922	11185	1443	3390	-319	785	1944	622
1923	13598	2208	4419	-389	1032	1925	781
1924	12681	2050	4228	-464	1170	1906	964
1925	13079	1627	4641	-485	1212	1887	1125
1926	13954	1961	4876	-545	1335	1868	1294
1927	13095	1897	5027	-650	1465	1848	1457
1928	13069	1871	5474	-711	1588	1829	1589
1929	13612	1815	5894	-600	1942	1810	1818
1930	11921	1718	6148	-496	1969	1791	1897
1931	9743	1484	5304	-339	1715	1777	1987
1932	8041	1283	4830	-240	1594	1762	1844
1933	8323	1260	5143	-299	1600	1748	1845
1934	9008	1410	5136	-318	1819	1734	1982
1935	9336	1298	5799	-300	1974	1719	2101
1936	10697	1351	6426	-302	2221	1710	2327
1937	11286	1280	7004	-400	2468	1700	2501
1938	8811	1148	6921	-456	2348	1691	2521
1939	9854	1262	7327	-486	2539	1681	2663
1940	11290	1245	7662	-175	2726	1671	2829
1941	12893	1338	8343	-139	2851	1648	3110
1942	14149	1435	7987	-320	3102	1624	2564
1943	15557	1450	8538	-310	3481	1600	2058
1944	15447	1509	9923	-662	3775	1576	2112
1945	14661	1311	10199	-580	3973	1552	2462

Table continued next page.

TABLE A-1 continued

(Trillion Btu's)

YEAR	BITUMINOUS COAL[a]	ANTHRACITE COAL[a]	CRUDE PETROLEUM[a]	PETROLEUM PRODUCTS[a,b]	NATURAL GAS	FUEL WOOD[c]	GASOLINE, DIESEL[d]
1946	13110	1369	10270	-283	4089	1525	3298
1947	14600	1224	11065	-262	4518	1545	3628
1948	13622	1275	12085	-147	5033	1557	3916
1949	11673	958	11402	57	5289	1550	4170
1950	11900	1013	12304	402	6150	1563	4584
1951	12285	940	13867	107	7240	1536	4902
1952	10971	897	14240	132	7760	1476	5218
1953	11182	711	14912	180	8156	1420	5494
1954	9512	683	14830	260	8548	1394	5704
1955	10941	599	15956	372	9232	1424	6137
1956	11142	610	16994	424	9834	1416	6456
1957	10640	528	16960	368	10416	1333	6668
1958	9366	403	16250	1724	10995	1322	6868
1959	9332	478	16686	1713	11990	1352	7243
1960	9693	447	16861	1779	12699	1319	7441
1961	9502	404	17348	1641	13228	1294	7625
1962	9826	363	17822	1840	14121	1300	7932
1963	10353	361	18174	2100	14843	1323	8295
1964	10899	365	18194	2420	15648	1336	8730
1965	11580	328	18506	2882	16098	1333	9142
1966	12205	290	19315	3090	17393	1367	9681
1967	11982	274	20208	3084	18250	1338	10234
1968	12401	258	21091	3722	19580	1417	10774
1969	12509	224	21796	4166	21020	1439	11327
1970	12712	210	22367	4753	22029	1430	11867
1971	12000	187	30530	0	22470	1431	12690
1972	12390	150	32940	0	22700	1502	13513
1973	13280	142	34840	0	22530	1528	14207
1974	12890	132	32760	0	21770	1538	13667
1975	12880	122	32800	0	20000	1497	14014
1976	13700	123	35160	0 }e	20340	1711	14876
1977	14000	120	37160	0	19910	1836	15377
1978	13840	99	38000	0	20000	2035	16084
1979	15000	81	37100	0	20670	2149	15698
1980	15400	89	34230	0	20420	2218	14786

[a] Reference 24 (crude petroleum category includes gasoline and diesel fuel).

[b] Minus sign denotes exports exceeded imports. These figures were added to the crude petroleum figures for each year less the figures for gasoline and diesel, to provide the basis for interpolating emissions for residual and distillate oil.

[c] Reference 64 for 1949 to 1980. Consumption expressed in oven dried tons was converted to energy units assuming 17.2 million Btu per ton. For 1900 to 1948, fuel wood consumption reported for every fifth year in Reference 27 was normalized to the 1950 value reported in Reference 64. For intervening years, consumption was estimated by linear interpolation.

[d] Reference 54. Gasoline, diesel category is a subset of crude petroleum category. Consumption expressed in gallons was converted to energy units assuming 138,095 Btu/gal (5,800,000 Btu/bbl). For years prior to 1919, consumption was estimated based on the number of registered vehicles and the 1920 average consumption per vehicle.

[e] Net petroleum products are included with crude petroleum for 1971 to 1980.

TABLE A-2. SUMMARY OF SO_2 EMISSIONS BY STATE

STATE	1900*	1901	1902	1903	1904	1905*
ALABAMA	102.	108.	120.	128.	126.	138.
ARIZONA	135.	160.	185.	210.	234.	259.
ARKANSAS	80.	84.	95.	102.	101.	112.
CALIFORNIA	140.	142.	149.	152.	151.	157.
COLORADO	73.	75.	80.	83.	82.	87.
CONNECTICUT	100.	108.	110.	128.	127.	139.
DELAWARE	5.	5.	4.	5.	5.	6.
DISTRICT OF COLUMBIA	19.	20.	21.	23.	22.	24.
FLORIDA	58.	61.	66.	69.	69.	75.
GEORGIA	87.	91.	101.	107.	106.	116.
IDAHO	42.	46.	50.	54.	56.	61.
ILLINOIS	1459.	1543.	1713.	1850.	1822.	2012.
INDIANA	451.	484.	558.	610.	598.	676.
IOWA	458.	479.	527.	560.	552.	602.
KANSAS	261.	282.	317.	343.	349.	385.
KENTUCKY	208.	217.	240.	254.	251.	273.
LOUISIANA	141.	147.	163.	173.	171.	187.
MAINE	55.	61.	57.	72.	70.	77.
MARYLAND	111.	118.	122.	136.	134.	145.
MASSACHUSETTS	226.	238.	249.	274.	270.	292.
MICHIGAN	381.	419.	478.	529.	541.	605.
MINNESOTA	202.	217.	236.	263.	258.	287.
MISSISSIPPI	81.	85.	95.	101.	100.	109.
MISSOURI	449.	479.	538.	582.	579.	641.
MONTANA	310.	325.	342.	358.	369.	387.
NEBRASKA	192.	201.	219.	234.	231.	251.
NEVADA	7.	8.	9.	10.	10.	11.
NEW HAMPSHIRE	44.	49.	43.	56.	55.	60.
NEW JERSEY	274.	302.	297.	366.	359.	398.
NEW MEXICO	41.	42.	45.	48.	48.	51.
NEW YORK	694.	757.	725.	886.	870.	949.
NORTH CAROLINA	52.	55.	63.	68.	68.	76.
NORTH DAKOTA	15.	17.	18.	22.	22.	24.
OHIO	982.	1035.	1158.	1242.	1221.	1349.
OKLAHOMA	67.	76.	96.	109.	106.	127.
OREGON	13.	14.	16.	18.	18.	20.
PENNSYLVANIA	745.	826.	814.	1011.	989.	1103.
RHODE ISLAND	49.	54.	48.	61.	60.	65.
SOUTH CAROLINA	32.	34.	39.	42.	42.	47.
SOUTH DAKOTA	15.	16.	17.	20.	19.	21.
TENNESSEE	149.	158.	177.	189.	189.	208.
TEXAS	389.	403.	431.	450.	451.	479.
UTAH	61.	70.	81.	90.	98.	108.
VERMONT	34.	39.	32.	44.	43.	47.
VIRGINIA	93.	99.	113.	123.	121.	136.
WASHINGTON	36.	39.	45.	49.	49.	55.
WEST VIRGINIA	84.	92.	108.	119.	118.	134.
WISCONSIN	256.	272.	298.	329.	323.	358.
WYOMING	28.	28.	29.	29.	28.	29.
THE U.S.	9988.	10681.	11535.	12785.	12681.	13959.

Footnotes at end of table.

TABLE A-2. Continued

SUMMARY OF SO2 EMISSIONS BY STATE(1000 TONS)

STATE	1906	1907	1908	1909	1910*	1911
ALABAMA	148.	164.	145.	160.	173.	147.
ARIZONA	277.	295.	309.	327.	344.	367.
ARKANSAS	120.	134.	117.	130.	141.	121.
CALIFORNIA	168.	181.	183.	195.	207.	201.
COLORADO	89.	94.	87.	91.	95.	84.
CONNECTICUT	143.	160.	145.	155.	165.	152.
DELAWARE	5.	6.	6.	6.	6.	6.
DISTRICT OF COLUMBIA	24.	25.	24.	25.	25.	26.
FLORIDA	79.	88.	80.	88.	94.	83.
GEORGIA	123.	135.	121.	132.	142.	124.
IDAHO	64.	67.	64.	68.	71.	69.
ILLINOIS	2135.	2371.	2100.	2313.	2488.	2146.
INDIANA	737.	849.	713.	817.	901.	716.
IOWA	630.	683.	618.	667.	706.	626.
KANSAS	401.	428.	399.	425.	446.	426.
KENTUCKY	287.	312.	282.	305.	323.	289.
LOUISIANA	198.	217.	195.	213.	228.	203.
MAINE	79.	91.	81.	87.	94.	84.
MARYLAND	150.	164.	150.	160.	169.	158.
MASSACHUSETTS	301.	325.	301.	319.	335.	315.
MICHIGAN	639.	705.	624.	684.	733.	611.
MINNESOTA	304.	344.	300.	333.	361.	306.
MISSISSIPPI	116.	129.	115.	126.	136.	119.
MISSOURI	679.	746.	670.	733.	784.	681.
MONTANA	385.	386.	373.	373.	373.	358.
NEBRASKA	261.	280.	257.	274.	288.	272.
NEVADA	26.	42.	53.	68.	84.	81.
NEW HAMPSHIRE	59.	67.	63.	65.	68.	66.
NEW JERSEY	414.	481.	422.	462.	502.	440.
NEW MEXICO	53.	57.	53.	57.	60.	67.
NEW YORK	965.	1091.	995.	1054.	1121.	1045.
NORTH CAROLINA	83.	96.	81.	93.	103.	79.
NORTH DAKOTA	26.	32.	27.	31.	34.	27.
OHIO	1431.	1584.	1397.	1539.	1654.	1427.
OKLAHOMA	154.	196.	160.	200.	234.	174.
OREGON	22.	25.	21.	24.	26.	21.
PENNSYLVANIA	1159.	1367.	1174.	1305.	1432.	1197.
RHODE ISLAND	64.	72.	68.	69.	73.	72.
SOUTH CAROLINA	51.	60.	50.	58.	64.	49.
SOUTH DAKOTA	23.	25.	23.	25.	27.	23.
TENNESSEE	219.	239.	216.	235.	250.	222.
TEXAS	495.	521.	501.	525.	546.	538.
UTAH	128.	149.	160.	181.	201.	205.
VERMONT	46.	53.	49.	50.	53.	52.
VIRGINIA	146.	166.	142.	161.	175.	142.
WASHINGTON	59.	68.	59.	66.	73.	59.
WEST VIRGINIA	149.	174.	147.	171.	190.	151.
WISCONSIN	379.	427.	373.	413.	446.	378.
WYOMING	30.	31.	30.	31.	32.	33.
THE U.S.	14721.	16400.	14722.	16088.	17274.	15237.

TABLE A-2. Continued

SUMMARY OF SO2 EMISSIONS BY STATE(1000 TONS)

STATE	1912	1913	1914	1915*	1916	1917
ALABAMA	186.	193.	211.	205.	218.	227.
ARIZONA	396.	422.	449.	474.	491.	509.
ARKANSAS	151.	156.	170.	165.	174.	182.
CALIFORNIA	209.	211.	215.	213.	211.	208.
COLORADO	98.	99.	105.	102.	100.	98.
CONNECTICUT	172.	178.	188.	185.	188.	195.
DELAWARE	6.	6.	6.	6.	6.	6.
DISTRICT OF COLUMBIA	25.	25.	25.	25.	25.	25.
FLORIDA	101.	105.	114.	112.	120.	127.
GEORGIA	150.	155.	168.	164.	174.	182.
IDAHO	79.	83.	89.	91.	89.	86.
ILLINOIS	2671.	2766.	3020.	2949.	2985.	3018.
INDIANA	991.	1037.	1168.	1127.	1238.	1328.
IOWA	744.	764.	820.	802.	788.	779.
KANSAS	446.	446.	454.	447.	442.	436.
KENTUCKY	340.	348.	372.	364.	384.	400.
LOUISIANA	241.	248.	267.	262.	263.	265.
MAINE	99.	105.	113.	110.	113.	120.
MARYLAND	175.	179.	188.	185.	186.	191.
MASSACHUSETTS	344.	352.	366.	361.	362.	369.
MICHIGAN	794.	826.	913.	887.	937.	974.
MINNESOTA	387.	402.	441.	428.	452.	474.
MISSISSIPPI	145.	149.	162.	158.	167.	174.
MISSOURI	838.	866.	941.	919.	921.	922.
MONTANA	367.	364.	365.	357.	340.	321.
NEBRASKA	296.	301.	313.	309.	307.	308.
NEVADA	85.	86.	88.	88.	86.	84.
NEW HAMPSHIRE	70.	73.	76.	74.	75.	80.
NEW JERSEY	534.	561.	609.	592.	629.	678.
NEW MEXICO	87.	101.	117.	129.	129.	128.
NEW YORK	1164.	1212.	1279.	1251.	1299.	1386.
NORTH CAROLINA	115.	121.	138.	132.	154.	171.
NORTH DAKOTA	38.	40.	45.	44.	46.	50.
OHIO	1761.	1816.	1974.	1923.	2006.	2073.
OKLAHOMA	280.	303.	356.	348.	373.	393.
OREGON	29.	30.	34.	33.	35.	37.
PENNSYLVANIA	1550.	1639.	1817.	1753.	1884.	2044.
RHODE ISLAND	74.	77.	79.	77.	77.	82.
SOUTH CAROLINA	71.	75.	85.	82.	92.	101.
SOUTH DAKOTA	28.	29.	32.	31.	32.	33.
TENNESSEE	264.	270.	290.	284.	298.	309.
TEXAS	563.	571.	586.	588.	593.	597.
UTAH	229.	243.	261.	271.	257.	242.
VERMONT	55.	58.	60.	59.	59.	64.
VIRGINIA	192.	200.	223.	216.	233.	247.
WASHINGTON	80.	83.	93.	90.	96.	100.
WEST VIRGINIA	215.	228.	260.	253.	275.	294.
WISCONSIN	479.	498.	547.	531.	579.	621.
WYOMING	32.	32.	32.	32.	32.	32.
THE U.S.	18446.	19132.	20726.	20290.	21020.	21769.

TABLE A-2. Continued

SUMMARY OF SO2 EMISSIONS BY STATE(1000 TONS)

STATE	1918	1919	1920*	1921	1922	1923
ALABAMA	234.	211.	224.	329.	301.	229.
ARIZONA	525.	537.	555.	580.	625.	687.
ARKANSAS	187.	176.	186.	32.	34.	219.
CALIFORNIA	204.	194.	192.	109.	199.	575.
COLORADO	96.	92.	90.	49.	63.	99.
CONNECTICUT	197.	182.	187.	138.	148.	214.
DELAWARE	6.	6.	6.	6.	7.	15.
DISTRICT OF COLUMBIA	25.	25.	25.	35.	33.	32.
FLORIDA	131.	118.	126.	66.	92.	197.
GEORGIA	187.	168.	179.	191.	190.	192.
IDAHO	84.	77.	76.	44.	45.	85.
ILLINOIS	3032.	2921.	2964.	2358.	2542.	3078.
INDIANA	1383.	1164.	1286.	2184.	1924.	1252.
IOWA	772.	797.	782.	25.	180.	864.
KANSAS	429.	413.	408.	70.	179.	466.
KENTUCKY	410.	372.	393.	722.	625.	369.
LOUISIANA	266.	264.	266.	59.	73.	367.
MAINE	122.	111.	116.	41.	52.	134.
MARYLAND	192.	186.	188.	44.	94.	254.
MASSACHUSETTS	370.	361.	365.	256.	298.	451.
MICHIGAN	990.	833.	890.	2026.	1689.	823.
MINNESOTA	487.	437.	464.	369.	391.	478.
MISSISSIPPI	178.	162.	172.	40.	41.	194.
MISSOURI	922.	913.	915.	772.	819.	948.
MONTANA	302.	275.	258.	207.	249.	329.
NEBRASKA	307.	308.	307.	19.	56.	345.
NEVADA	81.	75.	73.	58.	69.	96.
NEW HAMPSHIRE	80.	74.	76.	35.	39.	84.
NEW JERSEY	699.	605.	653.	322.	435.	910.
NEW MEXICO	127.	119.	120.	95.	109.	142.
NEW YORK	1415.	1265.	1337.	1433.	1337.	1465.
NORTH CAROLINA	182.	141.	164.	492.	395.	139.
NORTH DAKOTA	51.	45.	48.	14.	21.	52.
OHIO	2115.	1955.	2046.	2371.	2282.	2064.
OKLAHOMA	404.	351.	378.	91.	189.	465.
OREGON	38.	35.	37.	11.	21.	86.
PENNSYLVANIA	2118.	1816.	1980.	4333.	3552.	1917.
RHODE ISLAND	82.	77.	78.	66.	71.	126.
SOUTH CAROLINA	106.	86.	97.	192.	164.	93.
SOUTH DAKOTA	33.	32.	32.	7.	14.	36.
TENNESSEE	316.	287.	303.	509.	449.	290.
TEXAS	599.	591.	597.	270.	351.	880.
UTAH	227.	203.	189.	229.	259.	287.
VERMONT	65.	58.	60.	40.	37.	63.
VIRGINIA	255.	223.	241.	173.	197.	266.
WASHINGTON	103.	94.	100.	18.	28.	156.
WEST VIRGINIA	304.	252.	276.	498.	441.	282.
WISCONSIN	645.	549.	603.	1358.	1125.	543.
WYOMING	32.	32.	32.	21.	26.	41.
THE U.S.	22117.	20268.	21144.	23406.	22566.	23380.

TABLE A-2. Continued

SUMMARY OF SO2 EMISSIONS BY STATE(1000 TONS)

STATE	1924	1925*	1926	1927	1928	1929
ALABAMA	256.	246.	261.	246.	247.	257.
ARIZONA	712.	755.	721.	683.	647.	611.
ARKANSAS	138.	175.	190.	172.	170.	179.
CALIFORNIA	400.	504.	518.	495.	507.	530.
COLORADO	86.	93.	101.	96.	98.	103.
CONNECTICUT	188.	194.	186.	172.	171.	180.
DELAWARE	11.	12.	12.	13.	13.	13.
DISTRICT OF COLUMBIA	32.	31.	37.	35.	35.	35.
FLORIDA	151.	175.	179.	182.	184.	186.
GEORGIA	190.	191.	203.	193.	193.	200.
IDAHO	70.	78.	82.	81.	82.	85.
ILLINOIS	2882.	2967.	3081.	2935.	2932.	3027.
INDIANA	1508.	1401.	1474.	1392.	1387.	1435.
IOWA	604.	717.	769.	715.	713.	748.
KANSAS	355.	406.	440.	403.	400.	420.
KENTUCKY	466.	425.	436.	426.	426.	433.
LOUISIANA	203.	277.	303.	279.	281.	300.
MAINE	104.	110.	95.	88.	87.	92.
MARYLAND	188.	214.	208.	200.	201.	207.
MASSACHUSETTS	386.	411.	424.	389.	390.	413.
MICHIGAN	1148.	1005.	1020.	997.	997.	1012.
MINNESOTA	447.	456.	467.	437.	437.	456.
MISSISSIPPI	134.	161.	168.	162.	162.	167.
MISSOURI	902.	925.	983.	921.	919.	958.
MONTANA	325.	356.	358.	347.	343.	342.
NEBRASKA	236.	282.	306.	276.	276.	294.
NEVADA	91.	100.	103.	102.	103.	105.
NEW HAMPSHIRE	68.	68.	50.	45.	45.	48.
NEW JERSEY	710.	777.	821.	778.	782.	815.
NEW MEXICO	137.	148.	150.	146.	145.	147.
NEW YORK	1423.	1376.	1259.	1228.	1244.	1325.
NORTH CAROLINA	237.	196.	189.	196.	198.	194.
NORTH DAKOTA	41.	44.	43.	41.	41.	42.
OHIO	2144.	2112.	2230.	2110.	2108.	2186.
OKLAHOMA	370.	426.	444.	409.	399.	406.
OREGON	51.	67.	69.	69.	68.	68.
PENNSYLVANIA	2556.	2212.	2104.	1947.	1944.	2047.
RHODE ISLAND	101.	106.	88.	84.	83.	84.
SOUTH CAROLINA	120.	109.	107.	110.	111.	110.
SOUTH DAKOTA	28.	31.	30.	29.	29.	30.
TENNESSEE	352.	326.	310.	319.	317.	305.
TEXAS	663.	779.	810.	779.	784.	809.
UTAH	320.	352.	342.	329.	317.	306.
VERMONT	55.	52.	32.	29.	29.	31.
VIRGINIA	238.	251.	249.	250.	251.	252.
WASHINGTON	100.	126.	135.	127.	128.	134.
WEST VIRGINIA	351.	330.	333.	320.	315.	315.
WISCONSIN	766.	665.	669.	646.	646.	661.
WYOMING	35.	38.	40.	38.	39.	40.
THE U.S.	23080.	23263.	23629.	22468.	22418.	23146.

TABLE A-2. Continued

SUMMARY OF SO2 EMISSIONS BY STATE(1000 TONS)

STATE	1930*	1931	1932	1933	1934	1935*
ALABAMA	230.	194.	167.	186.	182.	189.
ARIZONA	571.	522.	473.	434.	384.	340.
ARKANSAS	146.	119.	97.	97.	107.	109.
CALIFORNIA	514.	456.	430.	572.	427.	454.
COLORADO	92.	79.	68.	69.	73.	75.
CONNECTICUT	160.	135.	115.	115.	126.	128.
DELAWARE	12.	12.	12.	12.	12.	12.
DISTRICT OF COLUMBIA	30.	25.	22.	24.	24.	24.
FLORIDA	187.	172.	165.	202.	168.	176.
GEORGIA	179.	151.	129.	136.	140.	145.
IDAHO	82.	76.	71.	68.	68.	66.
ILLINOIS	2740.	2328.	2004.	2054.	2175.	2231.
INDIANA	1276.	1063.	896.	927.	989.	1021.
IOWA	640.	515.	418.	434.	473.	491.
KANSAS	348.	271.	212.	228.	241.	252.
KENTUCKY	412.	353.	306.	315.	332.	341.
LOUISIANA	256.	207.	177.	231.	193.	209.
MAINE	86.	74.	64.	64.	70.	71.
MARYLAND	200.	176.	162.	192.	169.	177.
MASSACHUSETTS	353.	298.	254.	259.	277.	284.
MICHIGAN	968.	841.	740.	744.	767.	772.
MINNESOTA	399.	322.	261.	270.	295.	306.
MISSISSIPPI	155.	144.	134.	132.	141.	142.
MISSOURI	836.	685.	566.	578.	620.	636.
MONTANA	326.	310.	297.	296.	296.	295.
NEBRASKA	236.	182.	140.	146.	163.	171.
NEVADA	102.	96.	92.	98.	92.	93.
NEW HAMPSHIRE	48.	41.	35.	35.	38.	38.
NEW JERSEY	735.	597.	510.	684.	555.	594.
NEW MEXICO	140.	122.	105.	94.	83.	72.
NEW YORK	1245.	1032.	874.	961.	958.	983.
NORTH CAROLINA	208.	192.	178.	179.	184.	186.
NORTH DAKOTA	38.	32.	27.	28.	30.	31.
OHIO	1949.	1666.	1443.	1476.	1566.	1607.
OKLAHOMA	344.	280.	231.	250.	252.	261.
OREGON	64.	55.	51.	70.	53.	57.
PENNSYLVANIA	1842.	1478.	1197.	1271.	1358.	1410.
RHODE ISLAND	82.	71.	63.	74.	67.	70.
SOUTH CAROLINA	114.	104.	96.	97.	99.	100.
SOUTH DAKOTA	27.	23.	20.	21.	22.	22.
TENNESSEE	327.	312.	300.	306.	317.	324.
TEXAS	757.	644.	581.	773.	613.	660.
UTAH	291.	268.	246.	234.	221.	208.
VERMONT	33.	28.	23.	23.	26.	26.
VIRGINIA	256.	238.	226.	239.	232.	236.
WASHINGTON	119.	101.	90.	112.	94.	100.
WEST VIRGINIA	293.	256.	226.	229.	240.	244.
WISCONSIN	619.	525.	451.	463.	492.	505.
WYOMING	36.	32.	29.	31.	31.	32.
THE U.S.	21105.	17900.	15474.	16531.	16535.	16978.

TABLE A-2. Continued

SUMMARY OF SO2 EMISSIONS BY STATE(1000 TONS)

STATE	1936	1937	1938	1939	1940*	1941
ALABAMA	207.	215.	181.	195.	214.	245.
ARIZONA	406.	472.	538.	604.	670.	669.
ARKANSAS	113.	116.	119.	123.	126.	134.
CALIFORNIA	466.	474.	462.	470.	484.	559.
COLORADO	78.	82.	84.	87.	91.	91.
CONNECTICUT	136.	147.	138.	137.	151.	169.
DELAWARE	11.	12.	15.	13.	13.	15.
DISTRICT OF COLUMBIA	24.	27.	28.	26.	28.	30.
FLORIDA	187.	192.	172.	180.	192.	222.
GEORGIA	150.	153.	144.	148.	154.	172.
IDAHO	73.	79.	82.	89.	96.	96.
ILLINOIS	2491.	2608.	2150.	2348.	2623.	3053.
INDIANA	1128.	1176.	990.	1071.	1185.	1360.
IOWA	520.	532.	480.	502.	532.	597.
KANSAS	255.	256.	253.	254.	257.	279.
KENTUCKY	382.	400.	325.	357.	401.	470.
LOUISIANA	209.	208.	208.	208.	208.	224.
MAINE	70.	78.	81.	75.	81.	90.
MARYLAND	196.	211.	182.	191.	216.	255.
MASSACHUSETTS	294.	305.	291.	293.	309.	334.
MICHIGAN	873.	921.	746.	822.	930.	1049.
MINNESOTA	312.	316.	303.	308.	316.	352.
MISSISSIPPI	157.	163.	136.	147.	163.	194.
MISSOURI	675.	694.	634.	665.	705.	779.
MONTANA	326.	358.	389.	420.	451.	419.
NEBRASKA	172.	173.	171.	172.	173.	187.
NEVADA	112.	131.	150.	169.	188.	178.
NEW HAMPSHIRE	37.	44.	50.	43.	47.	52.
NEW JERSEY	578.	658.	719.	639.	689.	771.
NEW MEXICO	102.	132.	162.	192.	221.	220.
NEW YORK	965.	1126.	1214.	1067.	1180.	1259.
NORTH CAROLINA	215.	227.	174.	196.	226.	270.
NORTH DAKOTA	33.	34.	30.	31.	34.	38.
OHIO	1817.	1909.	1525.	1685.	1907.	2210.
OKLAHOMA	267.	273.	277.	284.	290.	309.
OREGON	58.	57.	55.	55.	56.	64.
PENNSYLVANIA	1449.	1566.	1554.	1512.	1626.	1756.
RHODE ISLAND	69.	76.	81.	75.	79.	82.
SOUTH CAROLINA	114.	120.	95.	106.	121.	142.
SOUTH DAKOTA	25.	26.	21.	23.	26.	31.
TENNESSEE	383.	410.	307.	353.	415.	502.
TEXAS	672.	678.	661.	670.	683.	761.
UTAH	292.	376.	457.	541.	626.	618.
VERMONT	23.	29.	37.	29.	32.	35.
VIRGINIA	276.	295.	223.	253.	295.	359.
WASHINGTON	103.	106.	108.	112.	115.	128.
WEST VIRGINIA	278.	291.	223.	248.	284.	330.
WISCONSIN	552.	575.	492.	524.	576.	657.
WYOMING	33.	33.	32.	33.	34.	40.
THE U.S.	18366.	19542.	17948.	18742.	20519.	22857.

TABLE A-2. Continued

SUMMARY OF SO2 EMISSIONS BY STATE(1000 TONS)

STATE	1942	1943	1944	1945*	1946	1947
ALABAMA	269.	300.	303.	291.	275.	294.
ARIZONA	668.	667.	664.	661.	749.	837.
ARKANSAS	140.	147.	145.	139.	106.	137.
CALIFORNIA	577.	736.	875.	882.	1061.	896.
COLORADO	90.	91.	87.	81.	68.	82.
CONNECTICUT	182.	196.	196.	187.	126.	188.
DELAWARE	17.	18.	19.	14.	19.	15.
DISTRICT OF COLUMBIA	32.	33.	32.	32.	43.	33.
FLORIDA	242.	278.	297.	294.	262.	304.
GEORGIA	186.	205.	207.	199.	174.	201.
IDAHO	96.	97.	93.	87.	85.	96.
ILLINOIS	3387.	3765.	3754.	3544.	3026.	3528.
INDIANA	1495.	1655.	1656.	1578.	1349.	1561.
IOWA	646.	703.	700.	669.	584.	667.
KANSAS	296.	316.	316.	305.	245.	304.
KENTUCKY	523.	584.	581.	548.	459.	547.
LOUISIANA	236.	256.	266.	264.	245.	271.
MAINE	97.	104.	105.	99.	68.	98.
MARYLAND	284.	320.	330.	307.	289.	307.
MASSACHUSETTS	353.	376.	377.	364.	221.	369.
MICHIGAN	1140.	1243.	1230.	1164.	1023.	1164.
MINNESOTA	381.	413.	412.	394.	287.	391.
MISSISSIPPI	218.	245.	245.	233.	170.	234.
MISSOURI	836.	902.	902.	869.	668.	856.
MONTANA	384.	355.	320.	278.	274.	301.
NEBRASKA	199.	212.	212.	205.	146.	203.
NEVADA	167.	158.	149.	136.	141.	149.
NEW HAMPSHIRE	56.	59.	59.	55.	37.	53.
NEW JERSEY	822.	918.	956.	928.	868.	916.
NEW MEXICO	218.	216.	213.	208.	207.	215.
NEW YORK	1308.	1404.	1383.	1409.	1236.	1407.
NORTH CAROLINA	305.	344.	344.	325.	304.	328.
NORTH DAKOTA	42.	46.	46.	44.	55.	45.
OHIO	2444.	2716.	2708.	2566.	2329.	2564.
OKLAHOMA	322.	339.	339.	330.	271.	341.
OREGON	67.	81.	91.	90.	91.	92.
PENNSYLVANIA	1853.	1968.	2010.	1918.	1777.	1925.
RHODE ISLAND	86.	84.	80.	76.	50.	75.
SOUTH CAROLINA	158.	176.	175.	165.	135.	166.
SOUTH DAKOTA	34.	37.	37.	35.	29.	35.
TENNESSEE	569.	647.	643.	600.	481.	588.
TEXAS	802.	924.	1015.	1024.	1094.	1079.
UTAH	609.	600.	587.	571.	570.	573.
VERMONT	38.	39.	40.	37.	27.	34.
VIRGINIA	406.	467.	471.	442.	392.	444.
WASHINGTON	133.	156.	169.	164.	173.	193.
WEST VIRGINIA	367.	408.	406.	385.	372.	388.
WISCONSIN	721.	790.	789.	747.	576.	744.
WYOMING	42.	51.	58.	58.	59.	60.
THE U.S.	24541.	26846.	27092.	26006.	23297.	26298.

TABLE A-2. Continued

SUMMARY OF SO2 EMISSIONS BY STATE(1000 TONS)

STATE	1948	1949	1950*	1951	1952	1953
ALABAMA	276.	257.	256.	208.	380.	354.
ARIZONA	918.	1007.	1091.	1118.	1140.	1167.
ARKANSAS	117.	76.	81.	90.	57.	62.
CALIFORNIA	607.	878.	593.	600.	584.	586.
COLORADO	75.	58.	61.	64.	56.	57.
CONNECTICUT	201.	120.	164.	147.	173.	161.
DELAWARE	23.	28.	31.	27.	42.	40.
DISTRICT OF COLUMBIA	40.	51.	51.	53.	44.	45.
FLORIDA	301.	258.	279.	321.	321.	341.
GEORGIA	198.	165.	179.	172.	198.	193.
IDAHO	101.	97.	105.	111.	99.	103.
ILLINOIS	3229.	2568.	2666.	2727.	2534.	2567.
INDIANA	1439.	1146.	1191.	1183.	1205.	1200.
IOWA	616.	508.	523.	569.	411.	436.
KANSAS	261.	185.	191.	214.	137.	150.
KENTUCKY	494.	380.	397.	338.	536.	504.
LOUISIANA	220.	199.	180.	191.	159.	166.
MAINE	91.	41.	56.	62.	48.	50.
MARYLAND	274.	249.	239.	243.	227.	228.
MASSACHUSETTS	368.	201.	279.	262.	283.	268.
MICHIGAN	1112.	932.	979.	989.	1013.	1021.
MINNESOTA	332.	195.	217.	236.	172.	182.
MISSISSIPPI	195.	115.	126.	143.	90.	100.
MISSOURI	731.	478.	507.	504.	516.	514.
MONTANA	297.	290.	300.	321.	321.	340.
NEBRASKA	166.	91.	100.	114.	64.	72.
NEVADA	149.	154.	157.	172.	181.	196.
NEW HAMPSHIRE	52.	17.	29.	32.	26.	27.
NEW JERSEY	771.	654.	602.	617.	533.	531.
NEW MEXICO	216.	213.	218.	222.	214.	217.
NEW YORK	1392.	1135.	1231.	1227.	1079.	1045.
NORTH CAROLINA	324.	297.	308.	316.	305.	309.
NORTH DAKOTA	53.	65.	65.	70.	55.	58.
OHIO	2452.	2147.	2210.	2272.	2073.	2106.
OKLAHOMA	297.	222.	233.	244.	215.	223.
OREGON	81.	82.	76.	79.	70.	71.
PENNSYLVANIA	1853.	1732.	1755.	1769.	1750.	1745.
RHODE ISLAND	92.	45.	73.	66.	84.	79.
SOUTH CAROLINA	167.	121.	142.	147.	127.	130.
SOUTH DAKOTA	33.	25.	27.	28.	24.	24.
TENNESSEE	511.	362.	375.	333.	493.	472.
TEXAS	843.	959.	790.	813.	824.	844.
UTAH	593.	578.	598.	563.	518.	482.
VERMONT	30.	8.	12.	12.	11.	10.
VIRGINIA	433.	366.	388.	409.	341.	351.
WASHINGTON	187.	196.	200.	218.	193.	202.
WEST VIRGINIA	383.	365.	371.	357.	405.	397.
WISCONSIN	638.	429.	456.	457.	449.	446.
WYOMING	50.	53.	47.	46.	45.	46.
THE U.S.	24284.	20801.	21203.	21477.	20826.	20920.

TABLE A-2. Continued

SUMMARY OF SO2 EMISSIONS BY STATE(1000 TONS)

STATE	1954	1955*	1956	1957	1958	1959
ALABAMA	572.	387.	379.	402.	463.	465.
ARIZONA	1188.	1219.	1263.	1309.	1359.	1403.
ARKANSAS	37.	55.	54.	46.	31.	28.
CALIFORNIA	564.	582.	515.	531.	464.	459.
COLORADO	46.	54.	55.	62.	86.	87.
CONNECTICUT	198.	159.	181.	186.	251.	253.
DELAWARE	59.	43.	44.	57.	101.	102.
DISTRICT OF COLUMBIA	34.	42.	50.	45.	46.	46.
FLORIDA	326.	367.	338.	362.	381.	382.
GEORGIA	225.	198.	194.	200.	214.	214.
IDAHO	87.	102.	92.	85.	73.	66.
ILLINOIS	2321.	2536.	2648.	2491.	2209.	2199.
INDIANA	1229.	1203.	1200.	1238.	1360.	1364.
IOWA	235.	406.	418.	401.	367.	367.
KANSAS	51.	135.	133.	128.	107.	106.
KENTUCKY	756.	540.	535.	547.	581.	582.
LOUISIANA	137.	162.	161.	159.	143.	144.
MAINE	43.	48.	56.	53.	56.	57.
MARYLAND	208.	224.	237.	244.	292.	294.
MASSACHUSETTS	298.	262.	340.	309.	373.	377.
MICHIGAN	1047.	1047.	1050.	1084.	1195.	1200.
MINNESOTA	101.	170.	188.	203.	291.	295.
MISSISSIPPI	71.	91.	94.	89.	76.	76.
MISSOURI	528.	516.	512.	526.	568.	569.
MONTANA	343.	370.	365.	351.	342.	331.
NEBRASKA	19.	62.	64.	63.	62.	62.
NEVADA	207.	223.	222.	220.	218.	216.
NEW HAMPSHIRE	21.	26.	28.	28.	33.	33.
NEW JERSEY	427.	506.	532.	508.	516.	516.
NEW MEXICO	211.	219.	214.	211.	208.	205.
NEW YORK	872.	974.	1134.	1074.	1253.	1262.
NORTH CAROLINA	294.	309.	328.	310.	278.	279.
NORTH DAKOTA	39.	56.	60.	56.	51.	51.
OHIO	1853.	2071.	1979.	2162.	2597.	2607.
OKLAHOMA	185.	224.	223.	202.	161.	153.
OREGON	59.	70.	65.	64.	55.	54.
PENNSYLVANIA	1720.	1751.	1755.	1739.	1761.	1751.
RHODE ISLAND	102.	81.	67.	78.	90.	90.
SOUTH CAROLINA	104.	126.	123.	126.	132.	132.
SOUTH DAKOTA	18.	23.	25.	23.	19.	19.
TENNESSEE	675.	509.	459.	584.	899.	908.
TEXAS	852.	880.	849.	850.	799.	795.
UTAH	435.	406.	389.	358.	319.	296.
VERMONT	8.	9.	12.	9.	9.	9.
VIRGINIA	265.	338.	327.	341.	370.	370.
WASHINGTON	169.	203.	200.	194.	176.	173.
WEST VIRGINIA	460.	406.	395.	425.	503.	506.
WISCONSIN	436.	443.	445.	487.	634.	639.
WYOMING	44.	45.	42.	48.	61.	62.
THE U.S.	20181.	20883.	21039.	21272.	22634.	22654.

TABLE A-2. Continued

SUMMARY OF SO2 EMISSIONS BY STATE(1000 TONS)

STATE	1960*	1961	1962	1963	1964	1965*
ALABAMA	448.	419.	467.	547.	631.	734.
ARIZONA	1446.	1532.	1618.	1705.	1792.	1879.
ARKANSAS	28.	28.	28.	27.	26.	26.
CALIFORNIA	461.	463.	461.	465.	486.	486.
COLORADO	82.	86.	94.	104.	115.	127.
CONNECTICUT	240.	235.	247.	265.	281.	304.
DELAWARE	91.	90.	93.	98.	103.	110.
DISTRICT OF COLUMBIA	47.	51.	56.	57.	51.	53.
FLORIDA	373.	386.	428.	467.	476.	527.
GEORGIA	209.	201.	224.	257.	287.	330.
IDAHO	59.	74.	90.	106.	123.	139.
ILLINOIS	2285.	2250.	2295.	2376.	2468.	2573.
INDIANA	1333.	1301.	1354.	1440.	1531.	1643.
IOWA	377.	371.	378.	392.	408.	425.
KANSAS	110.	111.	107.	103.	101.	95.
KENTUCKY	572.	544.	593.	672.	754.	856.
LOUISIANA	149.	151.	152.	153.	156.	157.
MAINE	58.	59.	63.	66.	67.	71.
MARYLAND	284.	270.	291.	327.	368.	414.
MASSACHUSETTS	373.	381.	411.	437.	437.	473.
MICHIGAN	1175.	1143.	1202.	1302.	1414.	1541.
MINNESOTA	275.	271.	275.	282.	292.	302.
MISSISSIPPI	81.	82.	82.	81.	82.	81.
MISSOURI	556.	582.	636.	700.	767.	840.
MONTANA	320.	324.	327.	330.	337.	340.
NEBRASKA	62.	60.	63.	69.	76.	83.
NEVADA	215.	212.	210.	208.	207.	206.
NEW HAMPSHIRE	32.	30.	32.	36.	39.	43.
NEW JERSEY	511.	495.	525.	574.	624.	685.
NEW MEXICO	200.	209.	232.	260.	288.	320.
NEW YORK	1232.	1232.	1289.	1356.	1376.	1456.
NORTH CAROLINA	293.	282.	295.	318.	343.	373.
NORTH DAKOTA	53.	54.	54.	52.	50.	48.
OHIO	2478.	2450.	2499.	2578.	2662.	2765.
OKLAHOMA	156.	148.	139.	131.	125.	116.
OREGON	56.	55.	53.	52.	54.	52.
PENNSYLVANIA	1730.	1705.	1707.	1725.	1742.	1761.
RHODE ISLAND	83.	85.	77.	66.	59.	46.
SOUTH CAROLINA	130.	127.	128.	131.	137.	141.
SOUTH DAKOTA	20.	20.	20.	20.	21.	22.
TENNESSEE	820.	825.	820.	812.	803.	792.
TEXAS	800.	803.	794.	786.	786.	773.
UTAH	278.	303.	325.	347.	368.	388.
VERMONT	9.	9.	10.	11.	11.	12.
VIRGINIA	360.	357.	369.	385.	401.	422.
WASHINGTON	175.	173.	167.	163.	165.	160.
WEST VIRGINIA	484.	456.	506.	586.	668.	771.
WISCONSIN	600.	590.	607.	635.	665.	701.
WYOMING	58.	56.	62.	70.	79.	90.
THE U.S.	22269.	22142.	22955.	24133.	25301.	26750.

TABLE A-2. Continued

SUMMARY OF SO2 EMISSIONS BY STATE(1000 TONS)

STATE	1966	1967	1968	1969	1970*	1971
ALABAMA	842.	806.	881.	901.	938.	995.
ARIZONA	1954.	2034.	2110.	2188.	2266.	2111.
ARKANSAS	27.	28.	31.	33.	34.	59.
CALIFORNIA	498.	507.	530.	545.	560.	544.
COLORADO	116.	111.	102.	95.	87.	96.
CONNECTICUT	254.	289.	279.	288.	288.	170.
DELAWARE	92.	99.	87.	85.	79.	79.
DISTRICT OF COLUMBIA	80.	76.	102.	113.	127.	78.
FLORIDA	568.	576.	627.	655.	686.	766.
GEORGIA	366.	359.	389.	401.	418.	470.
IDAHO	115.	98.	76.	56.	35.	36.
ILLINOIS	2605.	2599.	2630.	2643.	2659.	2559.
INDIANA	1860.	1782.	1926.	1963.	2033.	2048.
IOWA	402.	410.	395.	391.	383.	369.
KANSAS	114.	108.	121.	125.	131.	153.
KENTUCKY	1132.	1034.	1219.	1267.	1358.	1367.
LOUISIANA	159.	164.	170.	175.	179.	222.
MAINE	73.	76.	82.	86.	90.	82.
MARYLAND	430.	432.	454.	465.	477.	448.
MASSACHUSETTS	446.	490.	519.	550.	573.	370.
MICHIGAN	1676.	1630.	1724.	1749.	1795.	1723.
MINNESOTA	356.	339.	377.	388.	407.	381.
MISSISSIPPI	102.	98.	114.	120.	129.	185.
MISSOURI	942.	890.	955.	964.	989.	1047.
MONTANA	356.	371.	388.	403.	419.	373.
NEBRASKA	81.	83.	83.	84.	84.	77.
NEVADA	227.	246.	267.	287.	307.	299.
NEW HAMPSHIRE	66.	61.	80.	87.	97.	90.
NEW JERSEY	595.	649.	621.	628.	622.	478.
NEW MEXICO	374.	400.	446.	483.	523.	519.
NEW YORK	1383.	1436.	1429.	1445.	1449.	1360.
NORTH CAROLINA	482.	447.	523.	544.	582.	582.
NORTH DAKOTA	54.	52.	57.	58.	60.	63.
OHIO	3043.	2941.	3122.	3167.	3254.	3266.
OKLAHOMA	104.	105.	96.	92.	87.	86.
OREGON	53.	55.	57.	59.	61.	53.
PENNSYLVANIA	2122.	1998.	2257.	2326.	2453.	2314.
RHODE ISLAND	42.	49.	53.	58.	62.	36.
SOUTH CAROLINA	170.	164.	189.	198.	211.	216.
SOUTH DAKOTA	45.	37.	52.	56.	64.	59.
TENNESSEE	933.	885.	981.	1008.	1055.	1142.
TEXAS	784.	806.	823.	842.	860.	944.
UTAH	367.	347.	325.	305.	284.	250.
VERMONT	13.	12.	13.	13.	13.	10.
VIRGINIA	400.	436.	457.	482.	500.	484.
WASHINGTON	163.	164.	169.	172.	175.	171.
WEST VIRGINIA	881.	849.	930.	956.	998.	1074.
WISCONSIN	819.	778.	857.	878.	917.	867.
WYOMING	85.	88.	86.	86.	85.	95.
THE U.S.	28849.	28493.	30263.	30961.	31946.	31266.

TABLE A-2. Continued

SUMMARY OF SO2 EMISSIONS BY STATE(1000 TONS)

STATE	1972	1973	1974	1975*	1976	1977
ALABAMA	1063.	1194.	1123.	1117.	983.	932.
ARIZONA	1955.	1810.	1616.	1439.	1300.	1169.
ARKANSAS	74.	86.	70.	66.	35.	41.
CALIFORNIA	528.	508.	506.	498.	637.	767.
COLORADO	105.	122.	112.	111.	115.	113.
CONNECTICUT	79.	9.	56.	67.	57.	46.
DELAWARE	72.	50.	57.	56.	103.	143.
DISTRICT OF COLUMBIA	37.	2.	20.	25.	7.	7.
FLORIDA	826.	902.	835.	823.	963.	1074.
GEORGIA	559.	761.	669.	665.	663.	674.
IDAHO	36.	37.	33.	31.	26.	22.
ILLINOIS	2413.	2108.	2239.	2238.	1955.	1808.
INDIANA	2062.	2085.	2067.	2064.	2070.	2072.
IOWA	345.	292.	314.	314.	317.	317.
KANSAS	174.	212.	189.	186.	192.	205.
KENTUCKY	1377.	1395.	1383.	1381.	1318.	1293.
LOUISIANA	247.	266.	237.	229.	594.	952.
MAINE	77.	73.	77.	77.	48.	21.
MARYLAND	391.	257.	311.	310.	226.	234.
MASSACHUSETTS	241.	131.	254.	276.	429.	580.
MICHIGAN	1602.	1341.	1432.	1420.	1194.	1132.
MINNESOTA	344.	266.	300.	301.	231.	221.
MISSISSIPPI	222.	258.	219.	211.	226.	230.
MISSOURI	1173.	1496.	1322.	1295.	1275.	1275.
MONTANA	328.	284.	231.	182.	201.	217.
NEBRASKA	67.	47.	56.	56.	55.	57.
NEVADA	294.	299.	275.	260.	260.	258.
NEW HAMPSHIRE	84.	76.	81.	82.	95.	109.
NEW JERSEY	367.	235.	335.	347.	306.	262.
NEW MEXICO	512.	500.	492.	483.	443.	397.
NEW YORK	1230.	969.	1082.	1080.	759.	437.
NORTH CAROLINA	578.	567.	567.	565.	601.	634.
NORTH DAKOTA	68.	79.	73.	73.	87.	90.
OHIO	3264.	3246.	3239.	3234.	3065.	2996.
OKLAHOMA	85.	83.	78.	75.	96.	103.
OREGON	49.	45.	48.	49.	46.	39.
PENNSYLVANIA	2171.	1955.	2062.	2062.	1975.	1886.
RHODE ISLAND	19.	7.	22.	25.	2.	2.
SOUTH CAROLINA	217.	213.	210.	209.	233.	236.
SOUTH DAKOTA	51.	33.	41.	41.	42.	42.
TENNESSEE	1296.	1648.	1485.	1476.	1392.	1363.
TEXAS	1023.	1152.	1054.	1035.	1207.	1325.
UTAH	218.	194.	152.	115.	107.	96.
VERMONT	8.	5.	6.	6.	7.	7.
VIRGINIA	442.	337.	376.	374.	165.	173.
WASHINGTON	177.	203.	193.	192.	255.	307.
WEST VIRGINIA	1241.	1657.	1479.	1477.	1397.	1371.
WISCONSIN	789.	618.	693.	694.	671.	663.
WYOMING	111.	147.	130.	129.	176.	202.
THE U.S.	30692.	30258.	29901.	29520.	28602.	28601.

TABLE A-2. Continued

SUMMARY OF SO2 EMISSIONS BY STATE(1000 TONS)

STATE	1978*	1979	1980*
ALABAMA	781.	804.	788.
ARIZONA	915.	862.	793.
ARKANSAS	123.	123.	88.
CALIFORNIA	532.	538.	574.
COLORADO	142.	153.	150.
CONNECTICUT	73.	71.	62.
DELAWARE	62.	82.	101.
DISTRICT OF COLUMBIA	14.	12.	6.
FLORIDA	824.	919.	997.
GEORGIA	705.	803.	818.
IDAHO	33.	32.	28.
ILLINOIS	1717.	1632.	1579.
INDIANA	1792.	2004.	2076.
IOWA	398.	358.	338.
KANSAS	230.	278.	281.
KENTUCKY	1366.	1241.	1184.
LOUISIANA	328.	355.	415.
MAINE	76.	75.	66.
MARYLAND	329.	376.	359.
MASSACHUSETTS	402.	396.	346.
MICHIGAN	1160.	1009.	905.
MINNESOTA	223.	205.	187.
MISSISSIPPI	325.	325.	264.
MISSOURI	1269.	1290.	1283.
MONTANA	168.	166.	163.
NEBRASKA	83.	81.	72.
NEVADA	236.	230.	220.
NEW HAMPSHIRE	69.	79.	87.
NEW JERSEY	325.	337.	329.
NEW MEXICO	283.	289.	284.
NEW YORK	1021.	1013.	934.
NORTH CAROLINA	589.	593.	583.
NORTH DAKOTA	99.	114.	121.
OHIO	2846.	2839.	2814.
OKLAHOMA	105.	138.	147.
OREGON	50.	58.	61.
PENNSYLVANIA	1797.	1962.	2011.
RHODE ISLAND	22.	20.	13.
SOUTH CAROLINA	296.	321.	304.
SOUTH DAKOTA	57.	50.	47.
TENNESSEE	1143.	1174.	1177.
TEXAS	1255.	1323.	1312.
UTAH	122.	119.	114.
VERMONT	9.	9.	7.
VIRGINIA	364.	369.	313.
WASHINGTON	292.	279.	280.
WEST VIRGINIA	1258.	1223.	1205.
WISCONSIN	744.	695.	667.
WYOMING	189.	228.	243.
THE U.S.	27249.	27653.	27197.

* Estimated by the method described in Chapter II. For the intervening years, the state total emissions were estimated by the procedure described in Chapter III.

TABLE A-3. SUMMARY OF NO_x EMISSIONS BY STATE

STATE	1900*	1901	1902	1903	1904	1905*
ALABAMA	92.	93.	96.	98.	98.	100.
ARIZONA	3.	3.	3.	3.	3.	4.
ARKANSAS	158.	158.	159.	160.	160.	161.
CALIFORNIA	49.	50.	53.	55.	55.	58.
COLORADO	26.	28.	31.	33.	32.	36.
CONNECTICUT	33.	36.	33.	41.	40.	43.
DELAWARE	3.	3.	2.	3.	3.	3.
DISTRICT OF COLUMBIA	7.	8.	8.	8.	8.	9.
FLORIDA	53.	53.	54.	55.	55.	55.
GEORGIA	72.	73.	75.	76.	76.	78.
IDAHO	7.	7.	8.	8.	8.	9.
ILLINOIS	206.	218.	231.	255.	251.	274.
INDIANA	73.	78.	86.	94.	93.	103.
IOWA	57.	60.	64.	68.	67.	72.
KANSAS	33.	34.	36.	38.	38.	41.
KENTUCKY	38.	39.	42.	44.	43.	46.
LOUISIANA	43.	44.	45.	47.	47.	48.
MAINE	24.	26.	23.	30.	29.	32.
MARYLAND	36.	38.	37.	43.	42.	45.
MASSACHUSETTS	77.	82.	83.	92.	91.	98.
MICHIGAN	74.	78.	83.	91.	90.	98.
MINNESOTA	49.	53.	52.	60.	59.	63.
MISSISSIPPI	48.	49.	50.	52.	51.	53.
MISSOURI	81.	84.	89.	94.	93.	99.
MONTANA	21.	22.	23.	24.	24.	26.
NEBRASKA	29.	30.	31.	34.	34.	36.
NEVADA	2.	2.	3.	3.	3.	4.
NEW HAMPSHIRE	19.	22.	18.	24.	24.	25.
NEW JERSEY	93.	104.	91.	122.	120.	131.
NEW MEXICO	5.	6.	6.	7.	7.	8.
NEW YORK	251.	277.	242.	316.	311.	335.
NORTH CAROLINA	33.	33.	35.	36.	36.	38.
NORTH DAKOTA	7.	8.	9.	11.	10.	12.
OHIO	173.	182.	200.	214.	211.	231.
OKLAHOMA	13.	14.	16.	18.	18.	20.
OREGON	20.	21.	21.	22.	22.	23.
PENNSYLVANIA	276.	308.	275.	362.	355.	388.
RHODE ISLAND	21.	23.	20.	26.	26.	28.
SOUTH CAROLINA	22.	22.	23.	24.	24.	25.
SOUTH DAKOTA	9.	9.	10.	11.	11.	12.
TENNESSEE	42.	43.	45.	47.	47.	49.
TEXAS	60.	61.	64.	66.	66.	69.
UTAH	7.	8.	9.	9.	9.	10.
VERMONT	16.	19.	14.	21.	20.	22.
VIRGINIA	40.	42.	45.	48.	47.	51.
WASHINGTON	19.	20.	22.	23.	23.	25.
WEST VIRGINIA	24.	26.	30.	32.	32.	35.
WISCONSIN	59.	62.	62.	70.	69.	74.
WYOMING	7.	8.	8.	8.	8.	9.
THE U.S.	2610.	2764.	2766.	3127.	3091.	3314.

Footnotes at end of table.

TABLE A-3. Continued

SUMMARY OF NOX EMISSIONS BY STATE(1000 TONS)

STATE	1906	1907	1908	1909	1910*	1911
ALABAMA	103.	106.	102.	106.	108.	103.
ARIZONA	4.	5.	4.	5.	5.	4.
ARKANSAS	162.	163.	162.	163.	164.	162.
CALIFORNIA	63.	67.	65.	75.	80.	79.
COLORADO	38.	41.	37.	41.	44.	38.
CONNECTICUT	43.	48.	45.	47.	50.	47.
DELAWARE	3.	3.	3.	3.	3.	3.
DISTRICT OF COLUMBIA	9.	9.	9.	9.	10.	10.
FLORIDA	56.	58.	56.	58.	59.	57.
GEORGIA	79.	82.	79.	82.	84.	80.
IDAHO	10.	11.	10.	11.	11.	10.
ILLINOIS	287.	318.	286.	311.	333.	295.
INDIANA	110.	125.	108.	122.	133.	109.
IOWA	75.	80.	74.	79.	83.	75.
KANSAS	51.	59.	54.	75.	84.	82.
KENTUCKY	48.	52.	48.	52.	54.	50.
LOUISIANA	50.	52.	50.	53.	54.	52.
MAINE	31.	36.	33.	35.	37.	34.
MARYLAND	46.	50.	47.	49.	51.	49.
MASSACHUSETTS	100.	108.	101.	106.	111.	106.
MICHIGAN	104.	117.	102.	113.	123.	101.
MINNESOTA	65.	71.	66.	70.	74.	68.
MISSISSIPPI	55.	57.	54.	56.	58.	55.
MISSOURI	103.	110.	102.	108.	113.	103.
MONTANA	27.	29.	27.	29.	30.	27.
NEBRASKA	37.	40.	37.	39.	41.	39.
NEVADA	4.	5.	4.	4.	5.	4.
NEW HAMPSHIRE	25.	28.	27.	27.	28.	28.
NEW JERSEY	131.	153.	139.	147.	157.	146.
NEW MEXICO	8.	9.	8.	9.	10.	8.
NEW YORK	333.	379.	354.	367.	388.	374.
NORTH CAROLINA	39.	42.	39.	41.	44.	39.
NORTH DAKOTA	13.	16.	13.	15.	17.	13.
OHIO	251.	280.	250.	288.	312.	277.
OKLAHOMA	25.	31.	27.	37.	43.	38.
OREGON	23.	24.	23.	25.	25.	24.
PENNSYLVANIA	412.	489.	438.	505.	553.	502.
RHODE ISLAND	27.	31.	29.	30.	31.	31.
SOUTH CAROLINA	26.	28.	26.	27.	29.	26.
SOUTH DAKOTA	12.	13.	12.	13.	14.	13.
TENNESSEE	51.	54.	50.	53.	55.	52.
TEXAS	71.	73.	72.	74.	77.	76.
UTAH	11.	12.	11.	12.	13.	11.
VERMONT	21.	24.	23.	23.	24.	24.
VIRGINIA	54.	59.	53.	58.	62.	54.
WASHINGTON	27.	30.	27.	30.	32.	28.
WEST VIRGINIA	48.	58.	50.	75.	86.	76.
WISCONSIN	76.	84.	77.	82.	87.	79.
WYOMING	9.	10.	9.	10.	10.	10.
THE U.S.	3455.	3829.	3525.	3850.	4102.	3773.

TABLE A-3. Continued

SUMMARY OF NOX EMISSIONS BY STATE(1000 TONS)

STATE	1912	1913	1914	1915 *	1916	1917
ALABAMA	111.	113.	117.	116.	119.	121.
ARIZONA	6.	6.	6.	6.	7.	8.
ARKANSAS	165.	166.	167.	167.	175.	178.
CALIFORNIA	81.	81.	84.	84.	107.	118.
COLORADO	46.	48.	52.	51.	51.	51.
CONNECTICUT	51.	54.	56.	56.	57.	61.
DELAWARE	3.	3.	3.	3.	3.	4.
DISTRICT OF COLUMBIA	10.	10.	10.	10.	10.	11.
FLORIDA	60.	61.	63.	63.	65.	67.
GEORGIA	85.	86.	89.	88.	91.	93.
IDAHO	12.	12.	13.	13.	13.	14.
ILLINOIS	352.	363.	392.	383.	389.	399.
INDIANA	144.	150.	167.	163.	179.	195.
IOWA	87.	89.	95.	94.	92.	91.
KANSAS	78.	75.	75.	69.	66.	66.
KENTUCKY	57.	58.	61.	60.	65.	69.
LOUISIANA	62.	65.	69.	73.	84.	88.
MAINE	38.	40.	43.	42.	42.	46.
MARYLAND	53.	55.	57.	56.	56.	58.
MASSACHUSETTS	115.	118.	123.	122.	124.	129.
MICHIGAN	134.	140.	156.	153.	167.	181.
MINNESOTA	77.	81.	86.	84.	88.	93.
MISSISSIPPI	60.	61.	63.	63.	64.	66.
MISSOURI	120.	123.	131.	130.	129.	129.
MONTANA	32.	32.	34.	34.	35.	36.
NEBRASKA	42.	43.	45.	45.	45.	45.
NEVADA	6.	6.	6.	6.	7.	7.
NEW HAMPSHIRE	29.	30.	31.	31.	31.	34.
NEW JERSEY	164.	173.	184.	180.	188.	205.
NEW MEXICO	11.	12.	13.	12.	13.	14.
NEW YORK	399.	419.	437.	430.	444.	482.
NORTH CAROLINA	46.	47.	51.	50.	56.	62.
NORTH DAKOTA	19.	20.	23.	22.	24.	26.
OHIO	335.	348.	375.	372.	373.	383.
OKLAHOMA	54.	59.	65.	71.	101.	113.
OREGON	26.	27.	28.	28.	29.	29.
PENNSYLVANIA	582.	612.	657.	640.	657.	708.
RHODE ISLAND	31.	33.	33.	33.	33.	36.
SOUTH CAROLINA	30.	31.	33.	33.	35.	38.
SOUTH DAKOTA	15.	16.	17.	16.	17.	17.
TENNESSEE	57.	58.	61.	61.	64.	67.
TEXAS	81.	83.	85.	88.	108.	117.
UTAH	14.	15.	16.	16.	17.	18.
VERMONT	25.	26.	27.	26.	26.	29.
VIRGINIA	66.	68.	75.	73.	77.	81.
WASHINGTON	34.	36.	39.	38.	40.	42.
WEST VIRGINIA	95.	99.	107.	107.	115.	121.
WISCONSIN	91.	95.	101.	100.	107.	116.
WYOMING	10.	10.	10.	10.	15.	16.
THE U.S.	4302.	4458.	4735.	4672.	4904.	5178.

TABLE A-3. Continued

SUMMARY OF NOX EMISSIONS BY STATE(1000 TONS)

STATE	1918	1919	1920*	1921	1922	1923
ALABAMA	123.	118.	122.	143.	142.	139.
ARIZONA	8.	7.	8.	10.	16.	35.
ARKANSAS	174.	175.	178.	157.	167.	211.
CALIFORNIA	108.	114.	124.	77.	220.	690.
COLORADO	51.	52.	52.	7.	17.	61.
CONNECTICUT	62.	57.	60.	59.	57.	70.
DELAWARE	4.	4.	4.	4.	4.	7.
DISTRICT OF COLUMBIA	12.	10.	11.	16.	15.	13.
FLORIDA	68.	66.	69.	59.	73.	117.
GEORGIA	95.	91.	94.	105.	104.	101.
IDAHO	14.	14.	14.	4.	6.	20.
ILLINOIS	403.	393.	402.	308.	338.	445.
INDIANA	203.	173.	192.	395.	337.	192.
IOWA	91.	96.	95.	22.	23.	112.
KANSAS	69.	68.	69.	34.	61.	140.
KENTUCKY	69.	64.	68.	122.	107.	69.
LOUISIANA	81.	85.	88.	45.	87.	233.
MAINE	47.	42.	44.	25.	27.	50.
MARYLAND	59.	57.	58.	25.	42.	102.
MASSACHUSETTS	130.	128.	131.	115.	126.	176.
MICHIGAN	190.	163.	181.	442.	368.	179.
MINNESOTA	95.	89.	94.	87.	87.	101.
MISSISSIPPI	66.	64.	66.	43.	44.	73.
MISSOURI	130.	132.	132.	79.	101.	165.
MONTANA	36.	35.	36.	12.	20.	57.
NEBRASKA	45.	47.	47.	15.	15.	56.
NEVADA	8.	7.	7.	2.	14.	52.
NEW HAMPSHIRE	34.	31.	32.	23.	21.	35.
NEW JERSEY	210.	186.	199.	187.	217.	399.
NEW MEXICO	15.	13.	14.	7.	10.	19.
NEW YORK	492.	444.	471.	660.	581.	572.
NORTH CAROLINA	65.	54.	62.	187.	151.	56.
NORTH DAKOTA	26.	24.	26.	8.	7.	30.
OHIO	400.	373.	387.	509.	477.	397.
OKLAHOMA	98.	99.	109.	68.	108.	221.
OREGON	30.	30.	30.	22.	42.	114.
PENNSYLVANIA	736.	642.	685.	1367.	1117.	684.
RHODE ISLAND	36.	33.	34.	33.	31.	47.
SOUTH CAROLINA	39.	35.	38.	76.	65.	38.
SOUTH DAKOTA	18.	17.	18.	7.	7.	22.
TENNESSEE	68.	63.	67.	105.	95.	69.
TEXAS	108.	112.	119.	73.	189.	541.
UTAH	19.	17.	18.	22.	22.	22.
VERMONT	30.	26.	27.	23.	20.	29.
VIRGINIA	84.	76.	81.	75.	82.	104.
WASHINGTON	43.	41.	44.	18.	32.	108.
WEST VIRGINIA	124.	112.	120.	218.	187.	106.
WISCONSIN	120.	105.	115.	261.	215.	109.
WYOMING	14.	14.	16.	7.	15.	43.
THE U.S.	5250.	4899.	5159.	6366.	6309.	7429.

TABLE A-3. Continued

SUMMARY OF NOX EMISSIONS BY STATE(1000 TONS)

STATE	1924	1925 *	1926	1927	1928	1929
ALABAMA	139.	141.	140.	130.	125.	124.
ARIZONA	25.	31.	32.	32.	32.	33.
ARKANSAS	203.	213.	204.	191.	179.	165.
CALIFORNIA	491.	625.	646.	655.	682.	735.
COLORADO	45.	53.	60.	56.	58.	65.
CONNECTICUT	67.	66.	60.	58.	59.	63.
DELAWARE	6.	6.	6.	7.	7.	7.
DISTRICT OF COLUMBIA	14.	14.	17.	17.	17.	18.
FLORIDA	98.	111.	160.	209.	259.	309.
GEORGIA	103.	104.	116.	123.	133.	145.
IDAHO	13.	17.	18.	17.	17.	18.
ILLINOIS	412.	429.	441.	422.	426.	452.
INDIANA	249.	227.	239.	230.	232.	244.
IOWA	76.	94.	102.	96.	97.	104.
KANSAS	111.	131.	138.	137.	138.	144.
KENTUCKY	85.	80.	85.	86.	89.	94.
LOUISIANA	195.	233.	243.	246.	255.	269.
MAINE	43.	43.	34.	32.	33.	35.
MARYLAND	76.	87.	83.	82.	84.	89.
MASSACHUSETTS	158.	168.	170.	161.	164.	175.
MICHIGAN	257.	228.	232.	229.	231.	239.
MINNESOTA	99.	100.	95.	93.	94.	98.
MISSISSIPPI	60.	67.	70.	70.	72.	75.
MISSOURI	140.	154.	163.	156.	157.	169.
MONTANA	41.	49.	51.	48.	48.	49.
NEBRASKA	42.	49.	51.	48.	49.	53.
NEVADA	32.	42.	43.	43.	42.	42.
NEW HAMPSHIRE	31.	29.	19.	18.	18.	20.
NEW JERSEY	312.	345.	360.	352.	364.	386.
NEW MEXICO	15.	17.	19.	18.	18.	20.
NEW YORK	584.	555.	482.	494.	513.	559.
NORTH CAROLINA	94.	80.	79.	82.	83.	84.
NORTH DAKOTA	21.	25.	24.	23.	23.	24.
OHIO	430.	421.	448.	431.	435.	460.
OKLAHOMA	200.	227.	249.	267.	285.	322.
OREGON	74.	96.	97.	97.	97.	96.
PENNSYLVANIA	847.	735.	641.	606.	612.	649.
RHODE ISLAND	41.	41.	31.	30.	31.	33.
SOUTH CAROLINA	49.	45.	61.	79.	96.	113.
SOUTH DAKOTA	16.	19.	19.	19.	20.	21.
TENNESSEE	80.	77.	79.	84.	87.	91.
TEXAS	394.	492.	536.	575.	620.	729.
UTAH	22.	22.	24.	24.	24.	26.
VERMONT	26.	24.	13.	12.	13.	14.
VIRGINIA	95.	101.	104.	107.	112.	118.
WASHINGTON	70.	90.	95.	93.	95.	99.
WEST VIRGINIA	127.	114.	118.	117.	118.	118.
WISCONSIN	153.	134.	131.	131.	133.	140.
WYOMING	42.	48.	49.	48.	47.	46.
THE U.S.	7002.	7302.	7378.	7381.	7622.	8183.

TABLE A-3. Continued

SUMMARY OF NOX EMISSIONS BY STATE(1000 TONS)

STATE	1930*	1931	1932	1933	1934	1935*
ALABAMA	111.	101.	96.	123.	106.	115.
ARIZONA	32.	25.	23.	48.	26.	33.
ARKANSAS	151.	129.	112.	116.	85.	75.
CALIFORNIA	747.	558.	480.	1067.	476.	592.
COLORADO	54.	46.	39.	42.	42.	43.
CONNECTICUT	62.	56.	49.	49.	53.	54.
DELAWARE	7.	7.	7.	7.	7.	7.
DISTRICT OF COLUMBIA	16.	15.	13.	13.	14.	16.
FLORIDA	359.	342.	333.	377.	330.	338.
GEORGIA	148.	136.	124.	122.	115.	112.
IDAHO	16.	15.	13.	16.	14.	16.
ILLINOIS	406.	359.	318.	339.	348.	363.
INDIANA	222.	193.	168.	177.	183.	190.
IOWA	90.	81.	72.	75.	80.	84.
KANSAS	136.	110.	97.	151.	98.	109.
KENTUCKY	93.	83.	73.	74.	72.	71.
LOUISIANA	271.	221.	198.	314.	183.	199.
MAINE	35.	32.	28.	28.	30.	31.
MARYLAND	91.	75.	66.	112.	70.	81.
MASSACHUSETTS	161.	139.	122.	143.	131.	138.
MICHIGAN	230.	208.	187.	190.	195.	199.
MINNESOTA	92.	82.	73.	74.	77.	79.
MISSISSIPPI	73.	82.	90.	99.	111.	121.
MISSOURI	149.	131.	115.	138.	125.	133.
MONTANA	43.	35.	30.	49.	35.	40.
NEBRASKA	46.	40.	36.	40.	40.	41.
NEVADA	40.	26.	21.	65.	23.	33.
NEW HAMPSHIRE	21.	19.	17.	16.	18.	18.
NEW JERSEY	379.	285.	241.	478.	260.	309.
NEW MEXICO	18.	17.	17.	23.	22.	25.
NEW YORK	563.	476.	416.	527.	446.	470.
NORTH CAROLINA	88.	83.	76.	75.	77.	78.
NORTH DAKOTA	22.	19.	16.	17.	18.	19.
OHIO	417.	370.	331.	336.	348.	354.
OKLAHOMA	326.	272.	233.	284.	183.	173.
OREGON	94.	72.	65.	141.	68.	85.
PENNSYLVANIA	628.	522.	431.	486.	476.	500.
RHODE ISLAND	34.	30.	27.	31.	29.	30.
SOUTH CAROLINA	132.	114.	95.	81.	65.	50.
SOUTH DAKOTA	20.	18.	17.	18.	18.	19.
TENNESSEE	97.	96.	90.	90.	91.	93.
TEXAS	744.	608.	556.	991.	565.	656.
UTAH	24.	22.	20.	25.	22.	24.
VERMONT	16.	14.	13.	12.	14.	14.
VIRGINIA	122.	110.	99.	120.	97.	101.
WASHINGTON	95.	74.	66.	128.	69.	83.
WEST VIRGINIA	116.	104.	93.	91.	92.	91.
WISCONSIN	137.	122.	110.	109.	110.	109.
WYOMING	44.	35.	29.	41.	24.	24.
THE U.S.	8018.	6812.	6039.	8167.	6182.	6638.

TABLE A-3. Continued

SUMMARY OF NOX EMISSIONS BY STATE(1000 TONS)

STATE	1936	1937	1938	1939	1940 *	1941
ALABAMA	117.	116.	103.	103.	104.	112.
ARIZONA	34.	35.	35.	36.	37.	37.
ARKANSAS	77.	78.	77.	78.	79.	79.
CALIFORNIA	604.	616.	610.	620.	626.	670.
COLORADO	46.	48.	45.	47.	50.	55.
CONNECTICUT	58.	64.	63.	62.	68.	77.
DELAWARE	7.	8.	9.	8.	9.	11.
DISTRICT OF COLUMBIA	17.	19.	20.	19.	21.	24.
FLORIDA	309.	278.	241.	211.	181.	192.
GEORGIA	117.	122.	122.	126.	131.	128.
IDAHO	17.	17.	16.	17.	18.	20.
ILLINOIS	406.	430.	368.	399.	442.	506.
INDIANA	211.	222.	192.	207.	228.	255.
IOWA	91.	95.	87.	92.	99.	109.
KANSAS	113.	117.	115.	118.	121.	134.
KENTUCKY	83.	90.	78.	87.	98.	109.
LOUISIANA	203.	208.	202.	205.	207.	215.
MAINE	30.	34.	37.	34.	36.	40.
MARYLAND	88.	96.	90.	93.	103.	117.
MASSACHUSETTS	142.	148.	146.	146.	151.	169.
MICHIGAN	224.	238.	203.	220.	245.	278.
MINNESOTA	84.	88.	86.	89.	93.	104.
MISSISSIPPI	128.	134.	129.	135.	143.	142.
MISSOURI	144.	151.	142.	150.	160.	176.
MONTANA	43.	45.	46.	48.	50.	58.
NEBRASKA	43.	44.	43.	43.	44.	48.
NEVADA	32.	31.	31.	31.	29.	34.
NEW HAMPSHIRE	17.	21.	25.	21.	23.	25.
NEW JERSEY	293.	333.	383.	334.	352.	398.
NEW MEXICO	28.	30.	29.	30.	32.	35.
NEW YORK	443.	521.	603.	512.	551.	589.
NORTH CAROLINA	90.	96.	82.	91.	102.	115.
NORTH DAKOTA	20.	20.	19.	20.	21.	25.
OHIO	400.	424.	355.	389.	435.	491.
OKLAHOMA	193.	212.	217.	234.	252.	251.
OREGON	85.	84.	82.	82.	81.	96.
PENNSYLVANIA	502.	556.	585.	546.	583.	641.
RHODE ISLAND	29.	33.	36.	33.	35.	37.
SOUTH CAROLINA	58.	63.	58.	64.	72.	77.
SOUTH DAKOTA	20.	21.	19.	21.	22.	25.
TENNESSEE	110.	119.	96.	109.	127.	142.
TEXAS	695.	733.	717.	747.	775.	831.
UTAH	26.	28.	26.	27.	29.	32.
VERMONT	12.	16.	20.	16.	17.	19.
VIRGINIA	115.	123.	102.	112.	126.	148.
WASHINGTON	80.	78.	78.	76.	72.	81.
WEST VIRGINIA	106.	114.	93.	104.	118.	132.
WISCONSIN	119.	126.	113.	118.	129.	145.
WYOMING	26.	27.	26.	27.	28.	31.
THE U.S.	6934.	7348.	7101.	7137.	7558.	8262.

TABLE A-3. Continued

SUMMARY OF NOX EMISSIONS BY STATE(1000 TONS)

STATE	1942	1943	1944	1945*	1946	1947
ALABAMA	121.	135.	141.	138.	143.	154.
ARIZONA	38.	39.	38.	38.	45.	49.
ARKANSAS	80.	87.	90.	89.	90.	103.
CALIFORNIA	691.	792.	878.	889.	1098.	975.
COLORADO	57.	62.	66.	67.	64.	78.
CONNECTICUT	73.	70.	72.	75.	65.	82.
DELAWARE	11.	10.	11.	9.	11.	12.
DISTRICT OF COLUMBIA	20.	16.	17.	20.	24.	23.
FLORIDA	197.	206.	214.	220.	220.	226.
GEORGIA	123.	122.	118.	110.	120.	145.
IDAHO	21.	23.	24.	24.	26.	28.
ILLINOIS	516.	535.	547.	544.	520.	589.
INDIANA	268.	288.	292.	288.	276.	313.
IOWA	109.	112.	116.	118.	120.	138.
KANSAS	138.	159.	179.	186.	202.	205.
KENTUCKY	115.	124.	124.	121.	119.	139.
LOUISIANA	231.	252.	266.	277.	301.	307.
MAINE	40.	41.	42.	42.	36.	46.
MARYLAND	123.	136.	146.	140.	156.	150.
MASSACHUSETTS	158.	155.	165.	174.	155.	190.
MICHIGAN	282.	289.	294.	297.	288.	332.
MINNESOTA	102.	102.	105.	109.	102.	125.
MISSISSIPPI	141.	143.	137.	127.	117.	137.
MISSOURI	175.	179.	187.	195.	192.	221.
MONTANA	57.	70.	83.	84.	86.	88.
NEBRASKA	48.	50.	53.	54.	55.	68.
NEVADA	35.	46.	56.	56.	66.	58.
NEW HAMPSHIRE	25.	24.	24.	24.	21.	26.
NEW JERSEY	389.	433.	483.	492.	580.	514.
NEW MEXICO	39.	46.	52.	54.	59.	67.
NEW YORK	546.	528.	527.	591.	582.	636.
NORTH CAROLINA	123.	135.	137.	134.	145.	158.
NORTH DAKOTA	25.	28.	30.	30.	35.	35.
OHIO	508.	536.	543.	538.	527.	584.
OKLAHOMA	239.	228.	223.	220.	232.	238.
OREGON	102.	127.	150.	155.	176.	159.
PENNSYLVANIA	641.	649.	676.	664.	643.	717.
RHODE ISLAND	36.	33.	32.	32.	27.	33.
SOUTH CAROLINA	79.	82.	82.	79.	74.	86.
SOUTH DAKOTA	26.	27.	27.	28.	27.	32.
TENNESSEE	156.	176.	177.	168.	148.	187.
TEXAS	868.	1000.	1116.	1147.	1297.	1241.
UTAH	34.	38.	40.	40.	41.	45.
VERMONT	19.	18.	18.	18.	17.	19.
VIRGINIA	159.	183.	195.	190.	208.	209.
WASHINGTON	84.	99.	111.	111.	122.	126.
WEST VIRGINIA	139.	148.	148.	145.	148.	158.
WISCONSIN	152.	159.	161.	157.	145.	175.
WYOMING	31.	35.	39.	38.	39.	43.
THE U.S.	8389.	8972.	9455.	9548.	9993.	10470.

TABLE A-3. Continued

SUMMARY OF NOX EMISSIONS BY STATE(1000 TONS)

STATE	1948	1949	1950*	1951	1952	1953
ALABAMA	147.	150.	154.	149.	207.	203.
ARIZONA	50.	56.	61.	63.	64.	65.
ARKANSAS	113.	111.	128.	132.	135.	136.
CALIFORNIA	735.	1007.	785.	811.	822.	833.
COLORADO	78.	71.	82.	91.	93.	97.
CONNECTICUT	91.	74.	90.	86.	102.	99.
DELAWARE	15.	16.	19.	18.	24.	23.
DISTRICT OF COLUMBIA	26.	29.	31.	32.	30.	30.
FLORIDA	222.	213.	216.	230.	234.	240.
GEORGIA	167.	170.	198.	200.	208.	205.
IDAHO	30.	29.	32.	34.	31.	33.
ILLINOIS	616.	560.	623.	630.	683.	685.
INDIANA	314.	283.	306.	312.	352.	355.
IOWA	153.	145.	168.	182.	177.	183.
KANSAS	192.	210.	207.	221.	222.	228.
KENTUCKY	142.	133.	148.	143.	199.	195.
LOUISIANA	299.	328.	334.	372.	391.	407.
MAINE	46.	32.	39.	41.	39.	40.
MARYLAND	120.	138.	116.	122.	123.	125.
MASSACHUSETTS	177.	160.	168.	165.	184.	180.
MICHIGAN	346.	317.	352.	356.	383.	385.
MINNESOTA	133.	115.	135.	145.	144.	149.
MISSISSIPPI	138.	121.	137.	148.	143.	147.
MISSOURI	223.	208.	229.	237.	253.	256.
MONTANA	78.	79.	74.	71.	66.	65.
NEBRASKA	71.	66.	77.	85.	84.	88.
NEVADA	40.	55.	38.	35.	34.	33.
NEW HAMPSHIRE	27.	16.	21.	22.	22.	22.
NEW JERSEY	351.	452.	321.	317.	311.	306.
NEW MEXICO	74.	79.	92.	103.	104.	108.
NEW YORK	668.	613.	669.	674.	678.	662.
NORTH CAROLINA	174.	176.	194.	201.	219.	223.
NORTH DAKOTA	36.	39.	40.	43.	38.	40.
OHIO	606.	567.	617.	636.	662.	671.
OKLAHOMA	228.	239.	238.	229.	227.	220.
OREGON	121.	149.	115.	110.	108.	106.
PENNSYLVANIA	719.	700.	738.	753.	773.	772.
RHODE ISLAND	37.	24.	32.	29.	38.	36.
SOUTH CAROLINA	91.	80.	90.	96.	100.	103.
SOUTH DAKOTA	32.	29.	32.	34.	32.	34.
TENNESSEE	184.	153.	176.	160.	234.	225.
TEXAS	1094.	1293.	1186.	1197.	1224.	1228.
UTAH	66.	56.	74.	75.	76.	77.
VERMONT	19.	11.	14.	14.	15.	15.
VIRGINIA	197.	213.	206.	219.	217.	224.
WASHINGTON	115.	125.	119.	121.	115.	117.
WEST VIRGINIA	163.	162.	173.	170.	197.	194.
WISCONSIN	173.	152.	168.	169.	181.	181.
WYOMING	46.	45.	49.	53.	57.	58.
THE U.S.	9985.	10247.	10309.	10535.	11056.	11104.

TABLE A-3. Continued

SUMMARY OF NOX EMISSIONS BY STATE(1000 TONS)

STATE	1954	1955*	1956	1957	1958	1959
ALABAMA	274.	224.	227.	237.	260.	266.
ARIZONA	67.	69.	78.	79.	86.	91.
ARKANSAS	138.	143.	142.	143.	141.	142.
CALIFORNIA	840.	863.	856.	878.	863.	887.
COLORADO	96.	105.	107.	111.	122.	125.
CONNECTICUT	120.	103.	112.	111.	121.	124.
DELAWARE	31.	24.	26.	29.	42.	43.
DISTRICT OF COLUMBIA	27.	29.	28.	28.	27.	27.
FLORIDA	238.	251.	246.	252.	259.	266.
GEORGIA	214.	207.	206.	210.	222.	224.
IDAHO	29.	34.	35.	37.	37.	40.
ILLINOIS	745.	715.	740.	751.	827.	833.
INDIANA	399.	379.	384.	399.	439.	448.
IOWA	172.	193.	186.	193.	198.	200.
KANSAS	226.	241.	233.	237.	231.	232.
KENTUCKY	263.	215.	220.	228.	252.	257.
LOUISIANA	420.	448.	480.	511.	539.	590.
MAINE	39.	42.	44.	44.	45.	45.
MARYLAND	124.	132.	136.	141.	159.	163.
MASSACHUSETTS	203.	186.	204.	199.	219.	222.
MICHIGAN	415.	403.	406.	432.	496.	509.
MINNESOTA	144.	159.	175.	175.	197.	203.
MISSISSIPPI	144.	153.	156.	157.	157.	162.
MISSOURI	273.	270.	279.	304.	339.	364.
MONTANA	64.	63.	63.	66.	69.	71.
NEBRASKA	84.	95.	97.	98.	100.	102.
NEVADA	34.	31.	27.	29.	26.	26.
NEW HAMPSHIRE	21.	22.	23.	24.	25.	26.
NEW JERSEY	299.	303.	317.	308.	306.	313.
NEW MEXICO	109.	118.	119.	120.	120.	121.
NEW YORK	665.	667.	716.	688.	696.	709.
NORTH CAROLINA	241.	238.	241.	244.	255.	259.
NORTH DAKOTA	32.	41.	42.	43.	43.	45.
OHIO	694.	700.	703.	738.	825.	841.
OKLAHOMA	220.	211.	207.	206.	199.	197.
OREGON	106.	104.	101.	107.	106.	111.
PENNSYLVANIA	790.	793.	800.	810.	828.	842.
RHODE ISLAND	48.	39.	38.	39.	41.	41.
SOUTH CAROLINA	106.	110.	111.	116.	130.	133.
SOUTH DAKOTA	31.	35.	35.	36.	36.	37.
TENNESSEE	317.	244.	239.	268.	337.	345.
TEXAS	1260.	1262.	1365.	1478.	1577.	1762.
UTAH	78.	79.	83.	79.	71.	73.
VERMONT	15.	15.	17.	16.	16.	16.
VIRGINIA	217.	235.	233.	249.	281.	288.
WASHINGTON	109.	117.	121.	126.	129.	137.
WEST VIRGINIA	227.	203.	209.	202.	189.	189.
WISCONSIN	193.	188.	192.	208.	259.	266.
WYOMING	62.	63.	63.	65.	70.	69.
THE U.S.	11663.	11563.	11867.	12248.	13012.	13486.

TABLE A-3. Continued

SUMMARY OF NOX EMISSIONS BY STATE(1000 TONS)

STATE	1960*	1961	1962	1963	1964	1965*
ALABAMA	262.	258.	277.	305.	335.	368.
ARIZONA	94.	98.	105.	111.	118.	124.
ARKANSAS	142.	146.	153.	160.	166.	172.
CALIFORNIA	901.	934.	988.	1043.	1103.	1154.
COLORADO	124.	125.	130.	136.	144.	151.
CONNECTICUT	123.	123.	129.	136.	146.	154.
DELAWARE	41.	41.	43.	46.	49.	52.
DISTRICT OF COLUMBIA	27.	28.	29.	28.	28.	28.
FLORIDA	263.	270.	289.	307.	321.	341.
GEORGIA	221.	223.	238.	256.	276.	297.
IDAHO	43.	43.	46.	48.	50.	52.
ILLINOIS	818.	821.	846.	880.	922.	960.
INDIANA	444.	447.	470.	498.	531.	563.
IOWA	197.	199.	205.	212.	222.	229.
KANSAS	232.	238.	247.	255.	265.	271.
KENTUCKY	254.	252.	267.	289.	313.	340.
LOUISIANA	627.	656.	704.	743.	788.	814.
MAINE	46.	46.	48.	50.	51.	53.
MARYLAND	161.	162.	176.	195.	214.	236.
MASSACHUSETTS	220.	222.	232.	244.	253.	266.
MICHIGAN	500.	503.	536.	579.	628.	677.
MINNESOTA	202.	205.	211.	218.	228.	234.
MISSISSIPPI	165.	172.	182.	189.	199.	205.
MISSOURI	374.	369.	364.	363.	362.	368.
MONTANA	73.	72.	72.	73.	76.	76.
NEBRASKA	103.	106.	110.	114.	121.	125.
NEVADA	26.	27.	30.	33.	36.	39.
NEW HAMPSHIRE	25.	25.	27.	28.	30.	32.
NEW JERSEY	315.	315.	330.	352.	376.	400.
NEW MEXICO	122.	123.	133.	144.	155.	168.
NEW YORK	715.	719.	741.	771.	798.	827.
NORTH CAROLINA	258.	260.	279.	301.	323.	351.
NORTH DAKOTA	46.	47.	48.	49.	49.	50.
OHIO	829.	835.	864.	900.	941.	979.
OKLAHOMA	195.	204.	219.	231.	245.	255.
OREGON	114.	116.	120.	125.	130.	134.
PENNSYLVANIA	845.	849.	862.	882.	905.	921.
RHODE ISLAND	41.	41.	40.	38.	36.	33.
SOUTH CAROLINA	131.	133.	139.	146.	154.	162.
SOUTH DAKOTA	38.	38.	39.	41.	42.	43.
TENNESSEE	329.	338.	351.	362.	374.	384.
TEXAS	1891.	1931.	1994.	2050.	2122.	2161.
UTAH	77.	80.	83.	85.	89.	90.
VERMONT	16.	17.	17.	17.	18.	18.
VIRGINIA	283.	288.	304.	323.	342.	364.
WASHINGTON	142.	145.	152.	158.	166.	171.
WEST VIRGINIA	194.	189.	202.	223.	245.	271.
WISCONSIN	257.	260.	274.	290.	309.	326.
WYOMING	67.	66.	69.	74.	79.	85.
THE U.S.	13610.	13809.	14408.	15100.	15871.	16579.

TABLE A-3. Continued

SUMMARY OF NOX EMISSIONS BY STATE(1000 TONS)

STATE	1966	1967	1968	1969	1970*	1971
ALABAMA	391.	388.	406.	412.	423.	458.
ARIZONA	131.	137.	143.	149.	155.	183.
ARKANSAS	172.	173.	173.	173.	175.	201.
CALIFORNIA	1201.	1246.	1299.	1348.	1395.	1448.
COLORADO	159.	157.	162.	163.	166.	180.
CONNECTICUT	149.	165.	169.	178.	185.	178.
DELAWARE	51.	52.	52.	53.	53.	55.
DISTRICT OF COLUMBIA	33.	34.	39.	42.	46.	39.
FLORIDA	385.	403.	444.	475.	507.	566.
GEORGIA	324.	333.	356.	371.	390.	425.
IDAHO	52.	53.	54.	55.	56.	61.
ILLINOIS	967.	996.	1011.	1032.	1050.	1079.
INDIANA	606.	602.	632.	644.	663.	685.
IOWA	243.	249.	262.	271.	281.	288.
KANSAS	285.	292.	305.	317.	327.	344.
KENTUCKY	391.	383.	421.	436.	458.	491.
LOUISIANA	823.	832.	842.	851.	860.	892.
MAINE	55.	57.	60.	63.	65.	64.
MARYLAND	244.	252.	262.	271.	280.	284.
MASSACHUSETTS	255.	276.	280.	291.	298.	287.
MICHIGAN	715.	724.	756.	775.	799.	803.
MINNESOTA	248.	252.	264.	271.	280.	290.
MISSISSIPPI	216.	222.	232.	241.	249.	276.
MISSOURI	401.	389.	410.	413.	423.	443.
MONTANA	78.	78.	80.	81.	82.	88.
NEBRASKA	128.	132.	138.	142.	147.	152.
NEVADA	43.	43.	45.	46.	47.	56.
NEW HAMPSHIRE	39.	39.	45.	48.	52.	52.
NEW JERSEY	399.	427.	443.	463.	480.	462.
NEW MEXICO	202.	200.	225.	239.	255.	269.
NEW YORK	833.	865.	887.	911.	934.	900.
NORTH CAROLINA	419.	407.	456.	475.	504.	514.
NORTH DAKOTA	62.	62.	71.	77.	83.	87.
OHIO	1052.	1035.	1081.	1094.	1122.	1152.
OKLAHOMA	279.	298.	322.	349.	369.	382.
OREGON	137.	142.	146.	150.	155.	157.
PENNSYLVANIA	982.	972.	1020.	1035.	1064.	1077.
RHODE ISLAND	34.	38.	40.	43.	46.	43.
SOUTH CAROLINA	181.	184.	200.	210.	221.	229.
SOUTH DAKOTA	49.	49.	53.	56.	58.	60.
TENNESSEE	412.	408.	429.	436.	449.	500.
TEXAS	2153.	2156.	2150.	2140.	2139.	2240.
UTAH	91.	90.	91.	89.	90.	97.
VERMONT	19.	20.	21.	22.	23.	23.
VIRGINIA	366.	384.	395.	409.	421.	425.
WASHINGTON	176.	183.	187.	192.	198.	216.
WEST VIRGINIA	299.	288.	306.	309.	318.	342.
WISCONSIN	355.	357.	379.	391.	406.	403.
WYOMING	106.	111.	129.	143.	156.	175.
THE U.S.	17390.	17635.	18372.	18847.	19403.	20123.

TABLE A-3. Continued

SUMMARY OF NOX EMISSIONS BY STATE(1000 TONS)

STATE	1972	1973	1974	1975 *	1976	1977
ALABAMA	493.	541.	505.	503.	506.	489.
ARIZONA	212.	253.	220.	205.	243.	247.
ARKANSAS	219.	228.	201.	171.	176.	176.
CALIFORNIA	1481.	1488.	1410.	1321.	1491.	1631.
COLORADO	200.	237.	220.	230.	284.	328.
CONNECTICUT	169.	159.	158.	158.	136.	117.
DELAWARE	55.	50.	50.	49.	62.	71.
DISTRICT OF COLUMBIA	33.	24.	29.	30.	21.	19.
FLORIDA	617.	659.	612.	616.	725.	793.
GEORGIA	471.	550.	503.	501.	525.	539.
IDAHO	66.	70.	66.	68.	102.	58.
ILLINOIS	1105.	1129.	1086.	1049.	991.	944.
INDIANA	711.	753.	722.	714.	829.	900.
IOWA	294.	302.	292.	283.	265.	269.
KANSAS	362.	387.	366.	358.	391.	455.
KENTUCKY	530.	591.	549.	534.	589.	645.
LOUISIANA	914.	932.	910.	913.	914.	1083.
MAINE	64.	64.	64.	65.	58.	51.
MARYLAND	281.	261.	262.	261.	245.	223.
MASSACHUSETTS	279.	272.	274.	276.	248.	211.
MICHIGAN	795.	761.	765.	774.	693.	662.
MINNESOTA	302.	319.	305.	304.	286.	281.
MISSISSIPPI	296.	310.	278.	237.	261.	260.
MISSOURI	475.	539.	505.	503.	503.	508.
MONTANA	94.	102.	94.	91.	113.	126.
NEBRASKA	160.	170.	162.	158.	141.	142.
NEVADA	73.	110.	93.	94.	117.	136.
NEW HAMPSHIRE	52.	51.	51.	51.	55.	57.
NEW JERSEY	448.	422.	428.	422.	399.	349.
NEW MEXICO	283.	301.	284.	274.	296.	294.
NEW YORK	849.	753.	774.	740.	649.	519.
NORTH CAROLINA	524.	531.	517.	513.	536.	540.
NORTH DAKOTA	93.	105.	98.	95.	113.	144.
OHIO	1182.	1221.	1182.	1172.	1207.	1290.
OKLAHOMA	394.	403.	393.	392.	426.	461.
OREGON	161.	164.	159.	162.	200.	232.
PENNSYLVANIA	1102.	1150.	1110.	1098.	1145.	1138.
RHODE ISLAND	41.	40.	41.	41.	31.	24.
SOUTH CAROLINA	236.	239.	230.	224.	246.	252.
SOUTH DAKOTA	64.	72.	68.	68.	72.	74.
TENNESSEE	563.	664.	602.	597.	587.	580.
TEXAS	2333.	2449.	2362.	2381.	2423.	2724.
UTAH	108.	126.	118.	125.	149.	150.
VERMONT	23.	23.	23.	24.	25.	25.
VIRGINIA	420.	390.	392.	388.	376.	327.
WASHINGTON	239.	280.	255.	254.	304.	338.
WEST VIRGINIA	386.	488.	444.	448.	482.	498.
WISCONSIN	399.	383.	386.	389.	413.	396.
WYOMING	197.	234.	204.	177.	269.	325.
THE U.S.	20850.	21750.	20823.	20501.	21319.	22104.

TABLE A-3. Continued

SUMMARY OF NOX EMISSIONS BY STATE(1000 TONS)

STATE	1978*	1979	1980*
ALABAMA	490.	535.	509.
ARIZONA	276.	323.	326.
ARKANSAS	220.	242.	222.
CALIFORNIA	1423.	1475.	1404.
COLORADO	270.	293.	310.
CONNECTICUT	155.	152.	142.
DELAWARE	52.	58.	60.
DISTRICT OF COLUMBIA	30.	27.	22.
FLORIDA	655.	691.	702.
GEORGIA	538.	571.	560.
IDAHO	76.	145.	111.
ILLINOIS	1028.	1037.	1017.
INDIANA	721.	800.	857.
IOWA	297.	325.	312.
KANSAS	424.	424.	449.
KENTUCKY	552.	559.	566.
LOUISIANA	1349.	639.	880.
MAINE	69.	68.	62.
MARYLAND	272.	294.	284.
MASSACHUSETTS	291.	291.	267.
MICHIGAN	776.	784.	727.
MINNESOTA	314.	322.	309.
MISSISSIPPI	269.	308.	276.
MISSOURI	556.	556.	541.
MONTANA	123.	129.	130.
NEBRASKA	185.	191.	172.
NEVADA	102.	103.	110.
NEW HAMPSHIRE	53.	56.	55.
NEW JERSEY	406.	451.	411.
NEW MEXICO	296.	337.	327.
NEW YORK	767.	795.	709.
NORTH CAROLINA	545.	576.	560.
NORTH DAKOTA	128.	129.	141.
OHIO	1217.	1170.	1181.
OKLAHOMA	453.	457.	486.
OREGON	195.	198.	202.
PENNSYLVANIA	1123.	1184.	1172.
RHODE ISLAND	38.	43.	36.
SOUTH CAROLINA	268.	282.	271.
SOUTH DAKOTA	86.	82.	78.
TENNESSEE	595.	618.	581.
TEXAS	2730.	2442.	2549.
UTAH	146.	168.	175.
VERMONT	26.	26.	25.
VIRGINIA	401.	436.	411.
WASHINGTON	306.	309.	298.
WEST VIRGINIA	446.	488.	500.
WISCONSIN	416.	466.	438.
WYOMING	259.	297.	327.
THE U.S.	22414.	22354.	22259.

* Estimated by the method described in Chapter II. For the intervening years, the state total emissions were estimated by the procedure described in Chapter III.

APPENDIX B

TOTAL NATIONAL EMISSIONS BY SEASON

LIST OF TABLES

TABLE PAGE

B-1 SO_2 EMISSIONS BY SEASON 102

B-2 SO_2 PERCENTAGE EMISSIONS BY SEASON 102

B-3 NO_x EMISSIONS BY SEASON 103

B-4 PERCENTAGE OF NO_x EMISSIONS BY SEASON 103

TABLE B-1. SO_2 EMISSIONS BY SEASON[a] (1000 TONS)

YEAR	WINTER	SPRING	SUMMER	FALL	TOTAL
1900	3460.4	1934.6	2383.4	2193.9	9972.2
1905	4866.4	2705.1	3304.7	3067.6	13943.8
1910	5850.5	3348.1	4280.0	3779.5	17258.2
1915	6993.6	3912.4	4986.7	4378.6	20271.3
1920	7222.5	4139.2	5195.2	4561.6	21118.5
1925	7909.5	4536.3	5815.8	5001.6	23263.1
1930	7176.2	4115.7	5361.0	4453.5	21106.4
1935	5687.6	3293.7	4414.2	3582.3	16977.8
1940	6668.7	4103.8	5355.5	4391.1	20519.1
1945	7854.2	5409.5	6996.0	5747.6	26007.3
1950	6573.1	4346.7	5618.9	4664.7	21203.4
1955	6306.8	4448.2	5513.2	4615.2	20883.4
1960	6569.5	4899.3	5812.3	4988.4	22269.5
1965	7490.1	6018.8	6955.1	6286.3	26750.3
1970	8625.5	7315.7	8114.4	7890.7	31946.3
1975	8118.0	6789.6	7380.0	7232.4	29520.0
1980	7343.2	6472.9	6853.6	6527.3	27197.0

TABLE B-2. PERCENTAGE SO_2 EMISSIONS BY SEASON[a]

YEAR	WINTER	SPRING	SUMMER	FALL	TOTAL
1900	34.7	19.4	23.9	22.0	100.0
1905	34.9	19.4	23.7	22.0	100.0
1910	33.9	19.4	24.8	21.9	100.0
1915	34.5	19.3	24.6	21.6	100.0
1920	34.2	19.6	24.6	21.6	100.0
1925	34.0	19.5	25.0	21.5	100.0
1930	34.0	19.5	25.4	21.1	100.0
1935	33.5	19.4	26.0	21.1	100.0
1940	32.5	20.0	26.1	21.4	100.0
1945	30.2	20.8	26.9	22.1	100.0
1950	31.0	20.5	26.5	22.0	100.0
1955	30.2	21.3	26.4	22.1	100.0
1960	29.5	22.0	26.1	22.4	100.0
1965	28.0	22.5	26.0	23.5	100.0
1970	27.0	22.9	25.4	24.7	100.0
1975	27.5	23.0	25.0	24.5	100.0
1980	27.0	23.8	25.2	24.0	100.0

[a] Winter = December, January, February
Spring = March, April, May
Summer = June, July, August
Fall = September, October, November

TABLE B-3. NO_x EMISSIONS BY SEASON[a] (1000 TONS)

YEAR	WINTER	SPRING	SUMMER	FALL	TOTAL
1900	689.7	429.5	553.1	496.7	2169.0
1905	930.0	568.4	720.5	651.6	2870.5
1910	1181.7	722.2	926.4	824.3	3654.6
1915	1372.9	819.6	1048.4	919.4	4160.4
1920	1465.9	898.3	1121.7	983.2	4469.1
1925	2227.1	1496.9	1920.4	1657.6	7302.0
1930	2389.3	1659.7	2132.7	1836.1	8017.8
1935	1938.3	1387.3	1792.2	1520.1	6637.9
1940	2214.5	1617.4	2010.4	1715.6	7557.9
1945	2616.0	2081.4	2616.0	2234.1	9547.6
1950	2927.6	2267.9	2742.1	2371.0	10308.6
1955	3237.6	2601.6	3029.5	2694.1	11562.8
1960	3742.8	3130.3	3538.6	3198.4	13610.1
1965	4476.4	3879.5	4294.0	3929.3	16579.2
1970	5141.7	4617.8	4986.4	4656.6	19402.5
1975	5330.2	4920.2	5227.7	5022.7	20500.9
1980	5720.6	5364.4	5653.8	5520.2	22259.0

TABLE B-4. PERCENTAGE NO_x EMISSIONS BY SEASON[a]

YEAR	WINTER	SPRING	SUMMER	FALL	TOTAL
1900	31.8	19.8	25.5	22.9	100.0
1905	32.4	19.8	25.1	22.7	100.0
1910	32.4	19.8	25.4	22.6	100.2
1915	33.0	19.7	25.2	22.1	100.0
1920	32.8	20.1	25.1	22.0	100.0
1925	30.5	20.5	26.3	22.7	100.0
1930	29.8	20.7	26.6	22.9	100.0
1935	29.2	20.9	27.0	22.9	100.0
1940	29.3	21.4	26.6	22.7	100.0
1945	27.4	21.8	27.4	23.4	100.0
1950	28.4	22.0	26.6	23.0	100.0
1955	28.0	22.5	26.2	23.3	100.0
1960	27.5	23.0	26.0	23.5	100.0
1965	27.0	23.4	25.9	23.7	100.0
1970	26.5	23.8	25.7	24.0	100.0
1975	26.0	24.0	25.5	24.5	100.0
1980	25.7	24.1	25.4	24.8	100.0

[a] Winter = December, January, February
Spring = March, April, May
Summer = June, July, August
Fall = September, October, November

APPENDIX C

TOTAL EMISSIONS BY RELEASE (STACK) HEIGHT

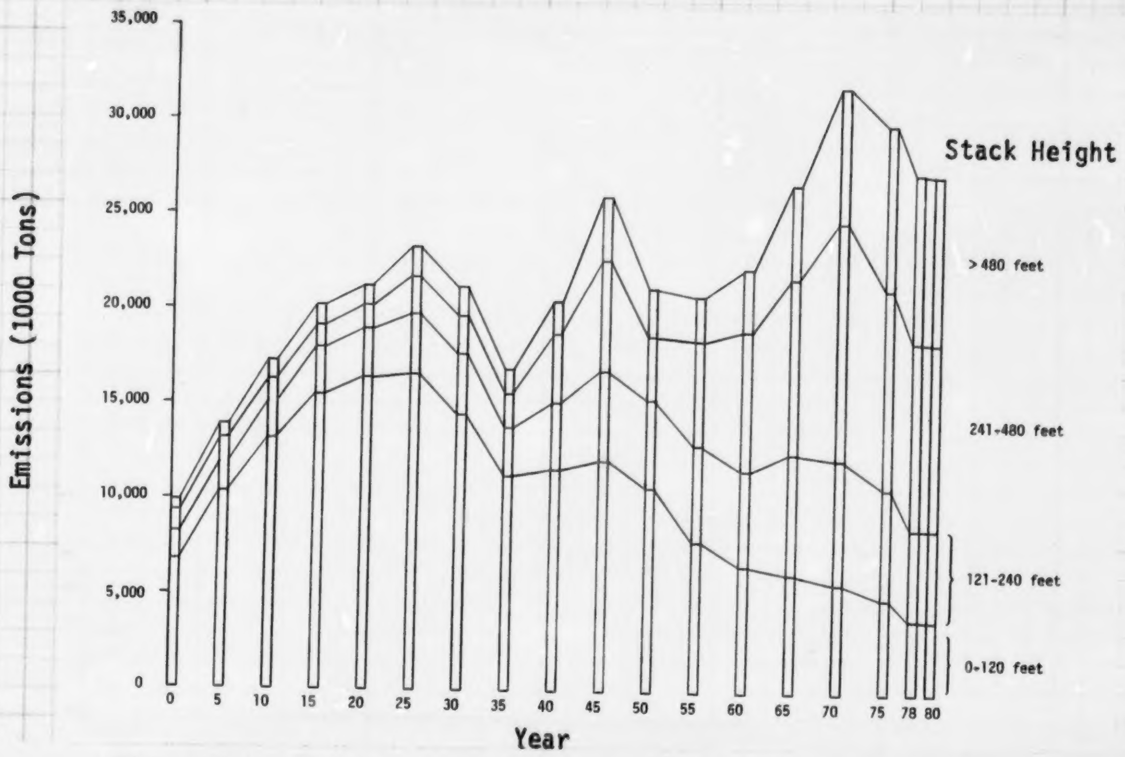

Figure C-1. Total national SO_2 emissions by stack height ranges.

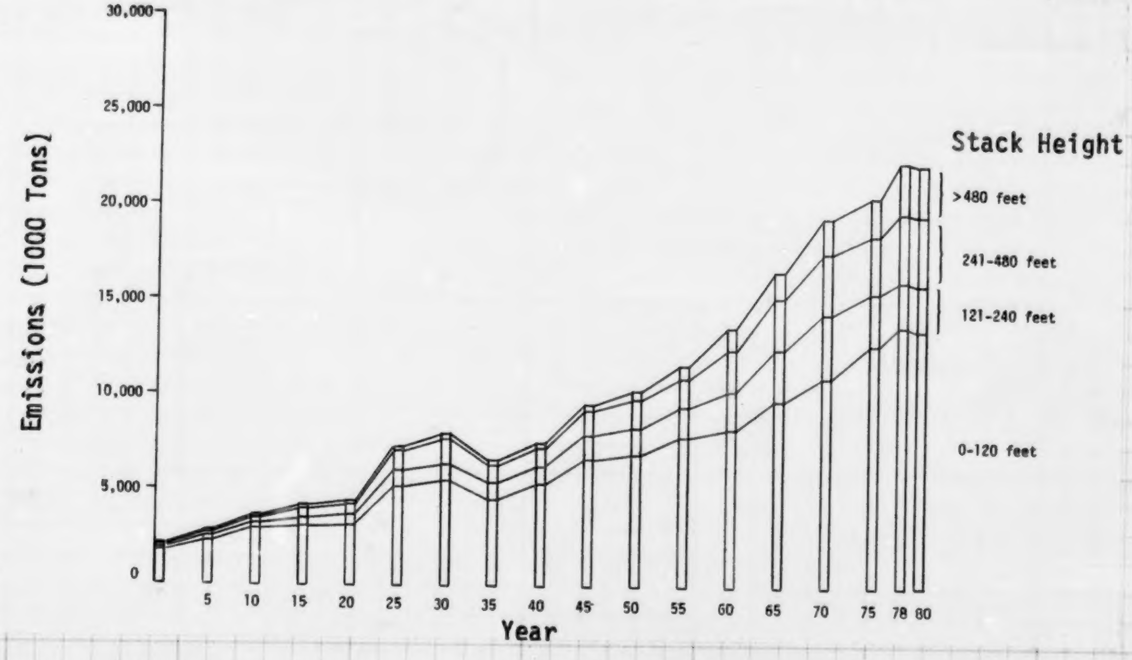

Figure C-2. Total national NO_x emissions by stack height ranges.